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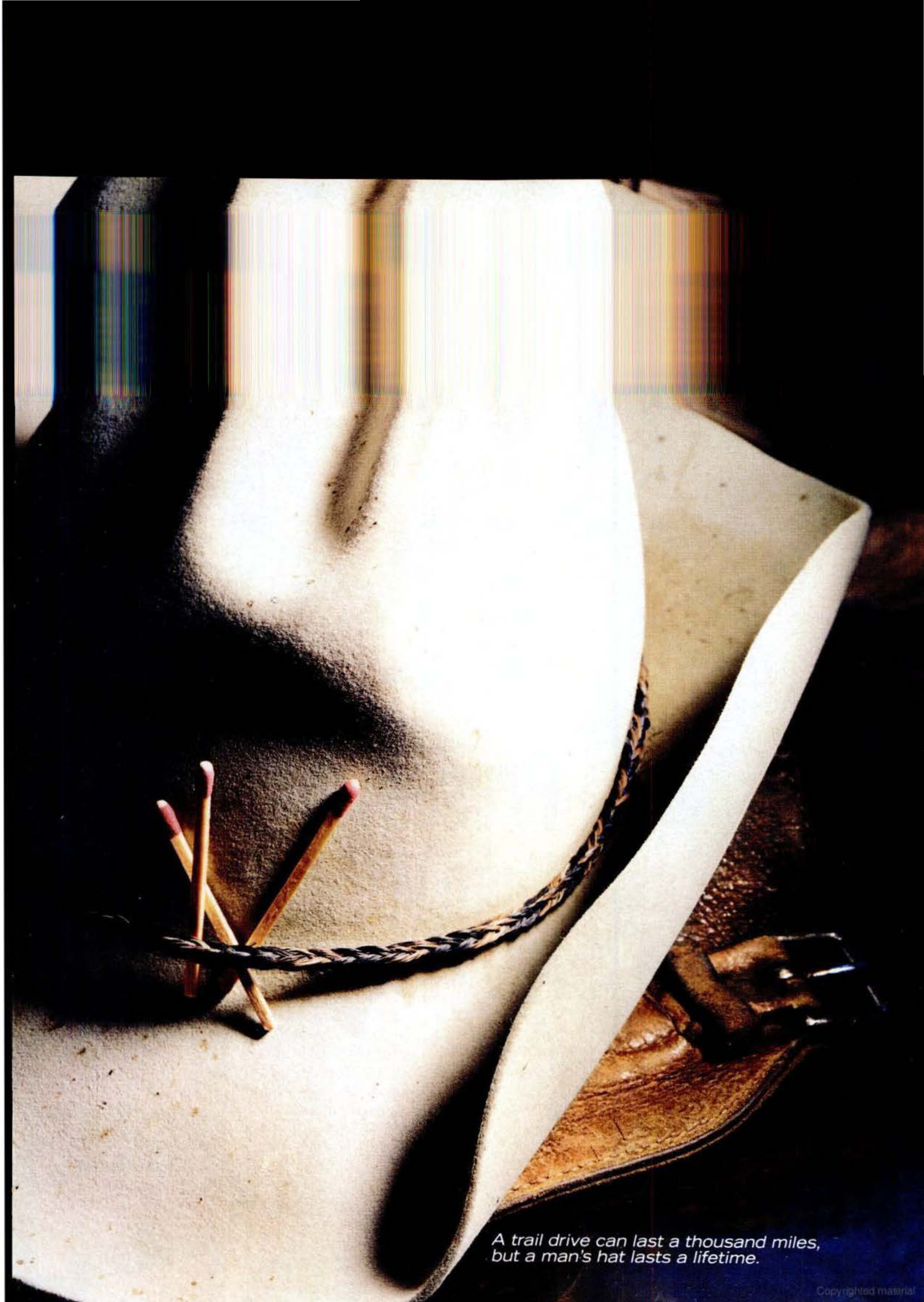

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*but a man's hat lasts a lifetime.*

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THE WHAT'S NEW MAGAZINE

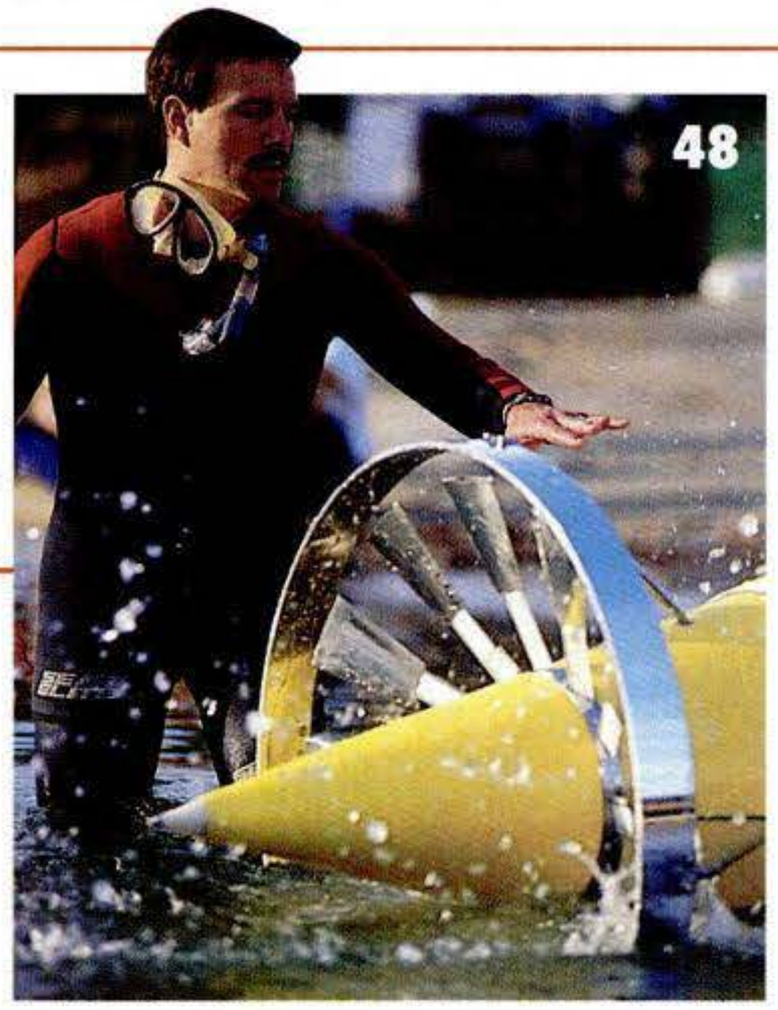
# Popular Science

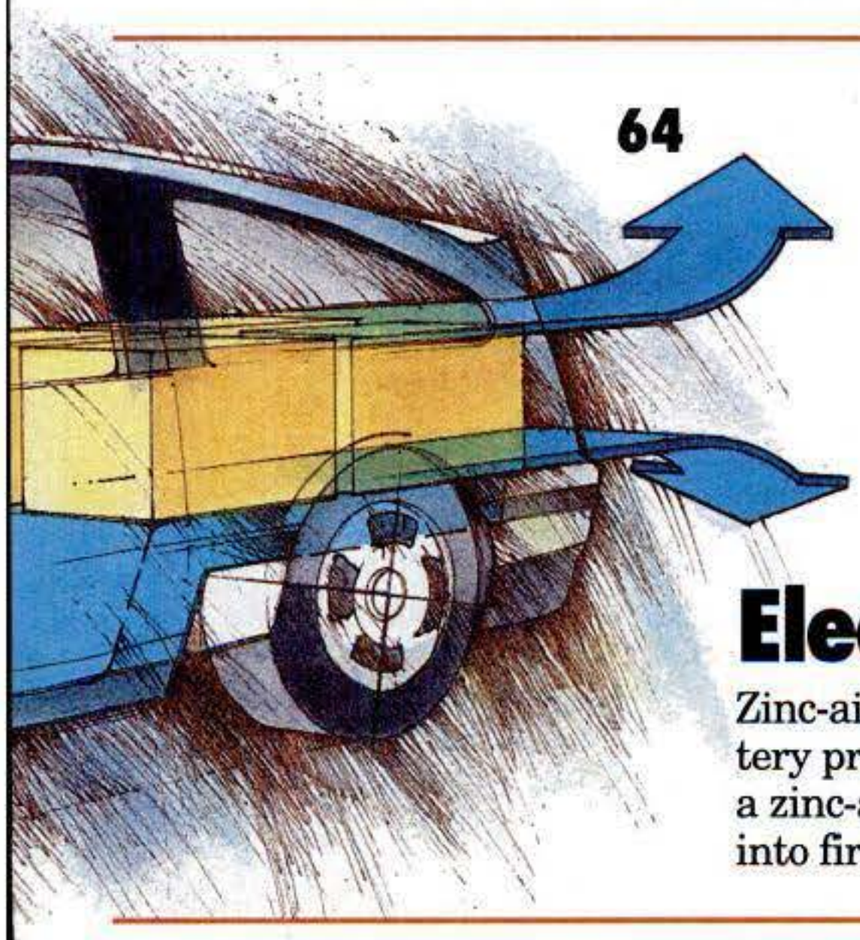
JULY 1991
Founded in 1872/Vol. 239, No. 1

COVER STORY

## Man-powered subs

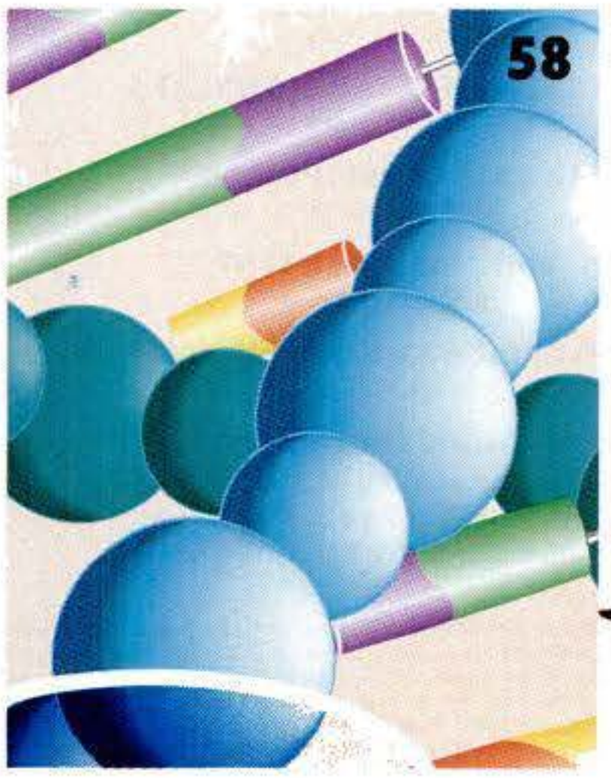
Arcane, high-tech, and just plain serious fun describe this year's subs at the Second International Submarine Races in June. Thirty-odd entrants will vie for the $5,000 grand prize.



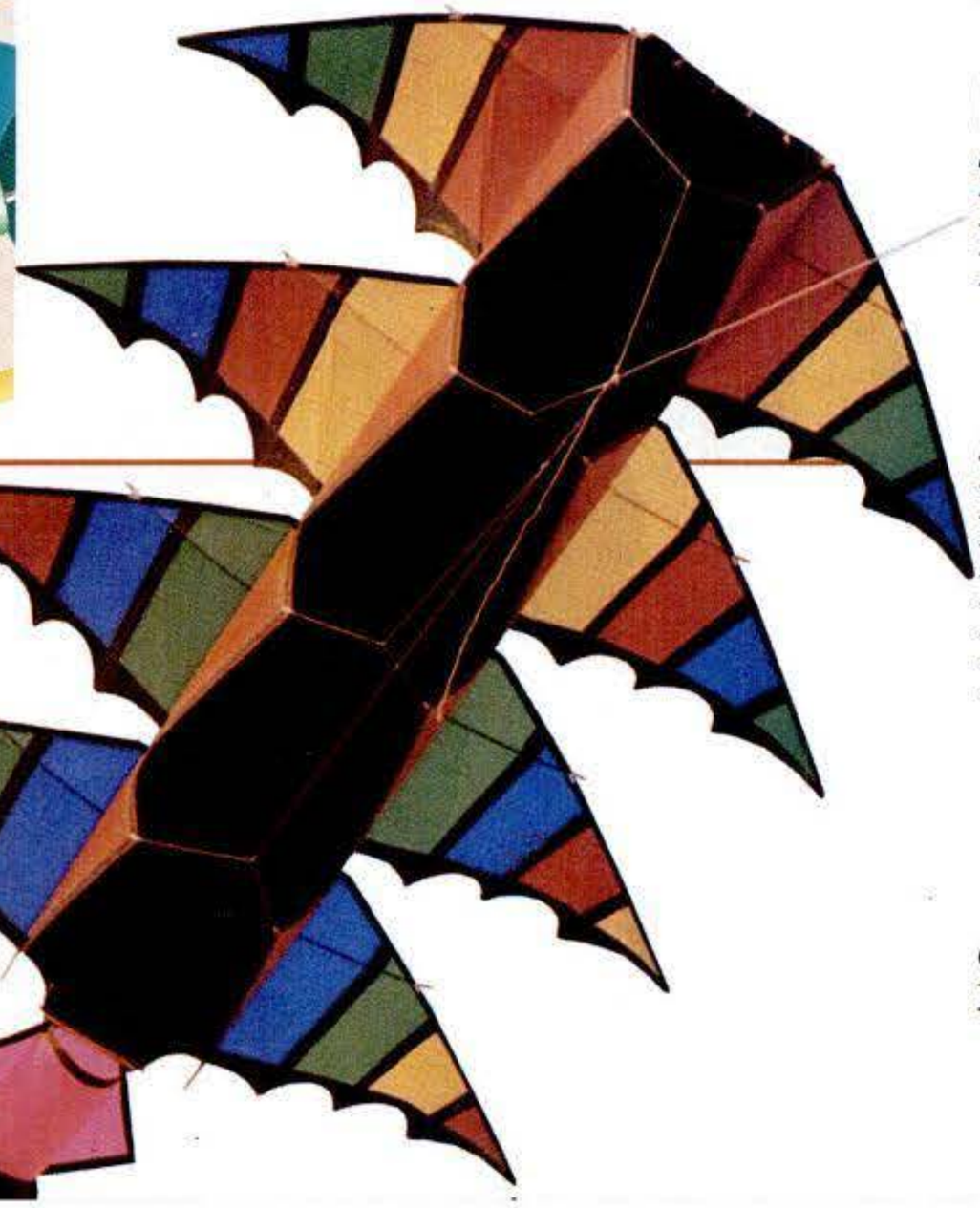

## Electric car showdown

Zinc-air cells have become one of the hottest battery prospects for practical electric cars; recently, a zinc-air-battery-equipped Honda CRX breezed into first place in an electric stock-car race.




## Genome

Geneticists are undertaking one of the most ambitious of all scientific missions. Called the human genome project, its goal is the mapping and isolation of all the genes in the human cell.




## The sky's no limit

High-tech materials born of science are reinventing the kite to once again delight and inspire. One kite even aims to set a new world altitude record.

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COVER BY
MARC ERICKSON



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# From The Editor

The human genome project, which contributor Edward Edelson reports on this month, is "big" science in every sense of the term. Its aim: to produce an encyclopedia of life—a data base of the human genetic code in its billions of sequences. Its promise: a greater understanding of the genetic underpinnings of chronic diseases, including diabetes, heart disease, cancer, arthritis, cystic fibrosis, muscular dystrophy, and more. Its scope: $3 billion over a decade and a half, involving hundreds of scientists from dozens of countries. We have already seen the dawning of the age of gene therapies on a limited scale. Ultimately, the human genome project could pave the way for such treatments to become widespread procedures.

"It is one of the most significant scientific efforts of our century," explains Edelson, "a program whose scope and effect on the human condition can be compared with that of the Manhattan Project." And like the quest to produce the atomic bomb—or any great exploration of the unknown—this one involves a high degree of controversial risk and uncertainty. This means you can find almost as many critics for the project as you can supporters. Some scientists are concerned about its moral conflicts, including the potential misuse of genetic information to stigmatize and curtail the rights of individuals. Others worry that the high cost of biology's first megaproject will drain funds from other research either more immediate in its impact or equally important in its potential benefits.

"The genome can be called a great biological continent, only a small part of which has been explored," notes Edelson. "The surprises that will emerge as the project proceeds are those to be expected when any unknown continent is mapped."

In this month's cover story, author Peter Britton again attempts to change the notion of submarine race watching. In 1989, Britton covered the First Annual International Submarine Races, a highly unorthodox aquatic event organized to stimulate interest and understanding in marine technology and ocean engineering. It must have worked because now, two years later, more than 30 teams are prepared to race beneath the waves again. From June 14 to 23, Riviera Beach, Fla., will be invaded by what is undoubtedly the world's most unusual gathering of underwater craft. Britton has interviewed submarine crews around the country to preview some of the human-powered subs likely to set the underwater pace, including *Team Effort* from landlocked Cookeville, Tenn., depicted on this month's cover by artist Marc Erickson.

The engineering and design that have gone into the man-powered submarines is impressive. So much so, in fact, that POPULAR SCIENCE will dedicate its Engineering Excellence Award to a college or university team. We will announce the winner of our $2,000 scholarship, and the race results, in the September issue.

When Senior Editor Stuart F. Brown gave POPULAR SCIENCE readers their first view of the Air Force's Advanced Tactical Fighter program in October 1986, he described a future scenario of thrust vectoring, stealthy supercruising, and advanced electronic avionics. In April, shortly after we published Brown's closeup profile of the two pairs of prototype ATF contenders, the future arrived. The superfighter duel fought in the skies over the Mojave Desert in California ended at a press conference in Washington, D.C.

Now that the Air Force has chosen the Lockheed/General Dynamics/Boeing YF-22 powered by a Pratt & Whitney engine as its fighter of the future, Brown provides a postscript in this month's "Science Newsfront." Did the best technology win? To date, Brown tells us, the Air Force refuses to be specific.

For a report on aerial technology of a more personal bent, be sure to take a tour of contributor Maxwell Eden's state-of-the-art kites. "The Sky's No Limit" might give you the inspiration and information you need for a personal high-tech adventure this summer. Unless, of course, submarine race watching is all you care to do.

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# Readers Talk Back

## Electric car critics

Many individuals believe that electric cars are non-polluting forms of transportation ["Electric Vehicles Only," May]. But of the methods of producing electricity—fuel-burning generators, nuclear reactors, and solar or other natural sources—only the last is non-polluting. Moreover, with the combined energy losses from the resistivity of electric cables, battery charging, the battery's internal resistance, and turning electricity back into kinetic energy with an electric motor, electric cars seem less efficient than conventional internal combustion engines.

Lance Lones, La Jolla, Calif.

If the power is supplied by the usual coal-fired plants, the electricity needed to charge the batteries of electric cars may produce more carbon dioxide than vehicles that burn gasoline. Rushing electric cars into production to meet legislative demands may solve local problems—but at the expense of creating greater difficulties for others.

A. Holmes, Zanesville, Ohio

## Politics before science?

I considered POPULAR SCIENCE an unbiased conveyor of scientific information until I read "A Conservation Agenda for the Outdoors" [Jan.], which shows that the magazine is controlled by money, power, and political influence. Its real agenda is to advance the interests of hunters, fishermen, and other outdoorsmen—a segment of the population that is guided by concerns that are political and not scientific. Further, the editorial appeals to people who have no real knowledge of the issues to pressure Congress, where political power, not facts, guides actions. Please cancel my subscription.

Andrew G. Detrick Bellefontaine, Ohio

*The readers of POPULAR SCIENCE and the nine other publications of Times Mirror Magazines share a common interest—the environment. That editorial's emphasis on outdoor recreation reflects one area where we can make a difference; future TMM Conservation Council editorials will cover topics relevant to all our readers. I'm sorry you feel people should not pressure Congress. This flies in the face of "government by and for the people." We hope to educate readers so that they can, if they choose to, play an effective role in the political process.—David Rockland, executive director, Times Mirror Magazines Conservation Council*

The editorial "Critical Environmental Questions" [April] reminded me of a related topic: I think we should redefine what wetlands are and which ones need protection. From July 1990 to February 1991, I worked for the North Carolina Hazardous Waste Management Commission, which was attempting to site hazardous-waste treatment facilities. North Carolina is covered from coast to mountains in wetlands, including man-made ones; the commission found that there weren't any geologically suitable sites that didn't also contain wetlands. While coastal habitats deserve protection, destroying a few man-made inland wetlands can hardly be considered an environmental threat. People tend to forget that "environment" includes not only the planet and atmosphere but also social and economic aspects. A balance of all these concerns could satisfy nearly everyone.

Andrea Hosler, Raleigh, N.C.

## Striving for fuel economy

As the White House ponders watered-down Corporate Average Fuel Economy (CAFE) standards, Ford admits "some fuel economy was sacrificed for improved acceleration" on its Crown Victoria Sedan ["Finessing the Full-Size Ford," Jan.]. Take note, President Bush: Detroit auto makers must be reminded that the oil crisis necessitates fuel economy in new automobiles. And without meaningful CAFE goals, we will continue to be dependent on imported oil and subject to price shocks, balance-of-trade problems, and oil blackmail.

Mark Ginsberg, energy director
Arizona Department of Commerce
Phoenix, Ariz.

*The public needs to be made conscious of energy conservation too—and given some incentive to buy the 50-mpg cars that are already on sale.*

---

Address letters to Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. Or fax your letter to us at 212-779-5468. Letters may be edited for space and clarity. We regret that we cannot answer unpublished letters.


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# The Golden Rule

## Your Tax Dollars and the Environment

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The best environmental legislation only has clout once money is appropriated to carry out the legislated programs. Although attention is focused primarily on passing legislation to establish better environmental policies, you can make an equal, if not greater impact by contacting your legislators during the appropriations process.

**The Process**

Early in February, President Bush proposed to Congress a budget for the federal government for Fiscal Year (FY) 1992 (October 1, 1991 to September 30, 1992). Congress is now debating his proposal and will try to pass a budget before October 1 for him to sign.

In Washington, the golden rule is "those who have the gold make the rules;" and Congress controls the gold. Only Congress can make the ultimate decision of whether a space shuttle is launched or potholes are filled on the interstate.

**Big Numbers**

The FY92 budget proposal estimates revenues of $1.165 trillion and expenditures of $1.446 trillion. Income tax from people like you is the greatest source of revenue. Direct payments to individuals, including social security, welfare and medicare, are the largest expenditures.

Although $1 trillion is an incredible amount of money, there is little discretionary money in this budget. After national defense, required distributions to states and individuals, interest and insurance payments, only 7% of the budget remains. However, a fifth of that is spent on natural resources and the environment.

**A Pretty Good Budget**

When the budget was announced, environmentalists were surprised. The FY92 proposal is the best budget in at least a decade for the environment and outdoor recreation, reconstructing many of the programs gutted during the Reagan years.

There are several parts of the proposed budget that we believe are worth supporting because of their combined environmental and outdoor recreation benefits:

• An increase of $196 million (33%) over 1991 for restoring and constructing recreation facilities on federal lands including national parks and forests, and improving public access for outdoor recreation. One part of this program, called "The National Forest: America's Great Outdoors," proposes spending $625 million over three years to meet the growing demand for outdoor recreation on National Forests, with $88 million to be spent in FY92. While this initiative could greatly benefit anyone who enjoys the outdoors, the programs to be funded have not yet been determined. Your support for specific types of recreation can help decide where these dollars go.

*Chart Illustrations by Andy Christie*

• A new $23 million initiative called "Coastal America" to protect the nation's coastal resources focusing on polluted coastal estuaries and eroded coastal wetlands.

• An increase of $230 million (48%) over 1991 for wetlands research, protection and enhancement including incentives to farmers to permanently protect 600,000 acres of wetlands under the 1990 Farm Bill and funds for the restoration of wetlands drained by the Army Corps of Engineers.

• The EPA's budget is increased $164 million (7%) over 1991. Most of the increase is used to implement and enforce the Clean Air Act changes.

**Deficiencies**

The FY92 budget is no bigger than the 1991 budget, so new expenditures come at the expense of existing programs. In some cases, these tradeoffs amount to shell games. Here are some problems:

• Although $88 million is allocated to the "new" recreation initiative in the Forest Service



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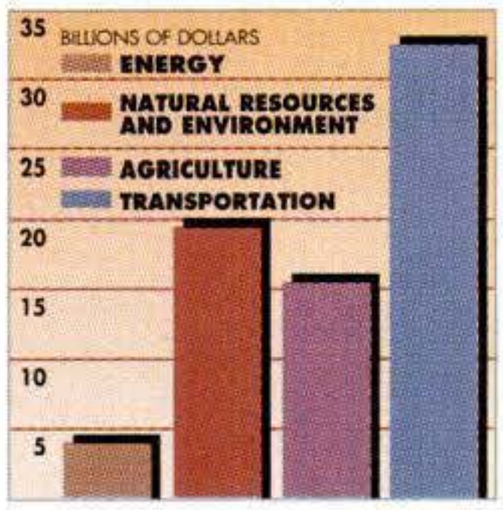
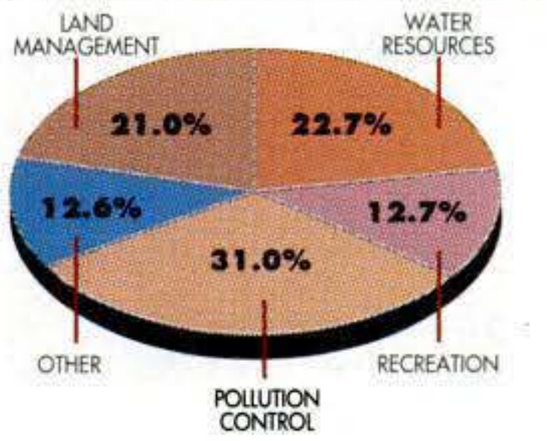
(part of the Department of Agriculture), $45 million is from existing recreation programs, making the real increase $43 million. Still, the focus on programs other than timber production in this agency is welcomed and needed.

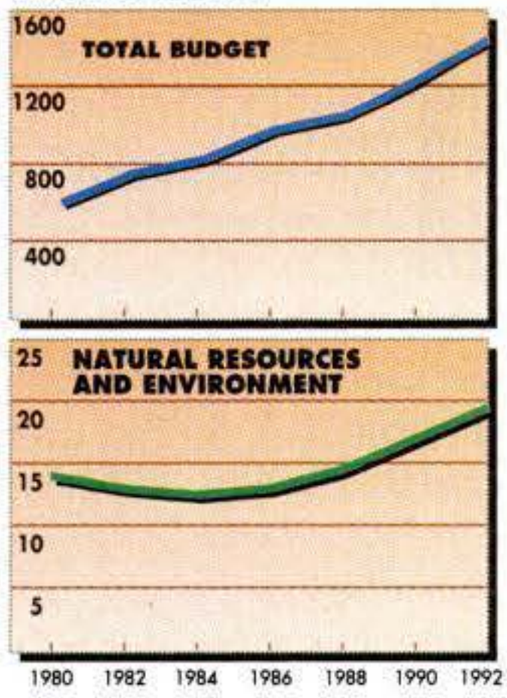
**COMPARISON OF VARIOUS SELECTED BUDGET CATEGORIES**
(FISCAL YEAR 1992 PROPOSED)




**NATURAL RESOURCES AND ENVIRONMENT BUDGET**
($19.5 BILLION TOTAL, FISCAL YEAR 1992 PROPOSED)




**HISTORICAL BUDGET CHANGES**
(BILLIONS OF DOLLARS)




• The increase in the Forest Service recreation budget is accompanied by a decrease in the wildlife and fisheries budget from $106.3 million to $92.8 million. Increases are needed in both the recreation and fish and wildlife budgets.

• The Bureau of Land Management wins an increase for recreation resources management. But the President's budget also calls for less money to purchase easements to allow public access to public lands. Increased public access must accompany expanded recreation programs.

• At a time when the country's marine fisheries are in the worst condition ever, the proposed budget calls for a reduction for the National Marine Fisheries Service (in the Department of Commerce) from $201 million to $173 million. More funds for research and management are a step toward restoring fish populations devastated by mismanagement and overfishing.

**Special Taxes for Special Programs**

A number of programs tax certain activities and then benefit those same taxpayers. One is the Aquatic Resources Trust Fund (commonly referred to as the Wallop-Breaux program) which taxes fishermen and boaters and dispenses the money to states for new sport fishing and boating opportunities. The "user pays-user benefits" premise is excellent, although it is disturbing that since this program was expanded in the mid-1980's from about $35 million a year to $200 million, participation in fishing has been flat or declining. One reason has been the use of some of the funds to replace money already being spent by the states, rather than creating new fishing and boating opportunities. While the Wallop-Breaux program has kept many state agency personnel employed, its benefits to those who pay the taxes need to be carefully reviewed.

A similar tax on hunting equipment has been used to restore species of wildlife devastated by habitat loss and commercial hunting in the 1800s and early 1900s. This successful system has been paid for by sport hunters but benefits anyone who enjoys seeing deer, ducks, geese and other species.

Other taxes work on the "user pays—someone else benefits" system. A classic example is the boat user fee passed last year in Congress, its proceeds going into the general treasury. Another is the luxury tax on boats, which has led to additional unemployment in a boating industry already hurt by the recession, thereby actually reducing tax revenue.

**Action You Can Take**

It's said that the only certainties in life are death and taxes. Little can be done about the former; but you, the taxpayer, can help decide where your money is spent. To do so, write to the Chairmen of the Appropriations Committees in the House and Senate as well as your own Congressman and Senators. The Chairmen are:

**The Honorable Jamie L. Whitten**
House Committee on Appropriations
Washington, D.C. 20515

**The Honorable Robert C. Byrd**
Senate Committee on Appropriations
Washington, D.C. 20510

In your letter, mention where you live and where you want your tax money spent. If you're in favor of the proposed FY92 budget, say so.

Here are some specific recommendations you could make:

1) Support the "National Forests: America's Great Outdoors" recreation initiative without taking away from the Forest Service's Fish and Wildlife budget. You should indicate the types of recreation programs you would like funded;

2) Increase the budget of the National Marine Fisheries Service;

3) Repeal user fees that don't benefit the user, including the boat user fee and the luxury tax on boats; and

4) Increase the purchase of easements for access to public lands.

Does one letter make a difference? Yes. Because when combined with hundreds of others, the politicians have to take notice. With 30 million readers of all of our Times Mirror magazines, you can be part of the solution. So take a few minutes and tell the people who spend your money where you want it to go. Together we can create a better environment.

**Questions? Write: Dr. David B. Rockland, TMM Conservation Council, 1705 DeSales St., Washington D.C. 20036**



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# A fistful of flavor for small change.

© The American Tobacco Co. 1991.

Filters: 14 mg. "tar", 1.1 mg. nicotine av. per cigarette by FTC method.

SURGEON GENERAL'S WARNING: Cigarette Smoke Contains Carbon Monoxide.

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# WHAT'S NEW

EDITED BY MARCELLE M. SOVIERO AND JUDITH ANNE YEAPLE

## GILDING THE LILY?

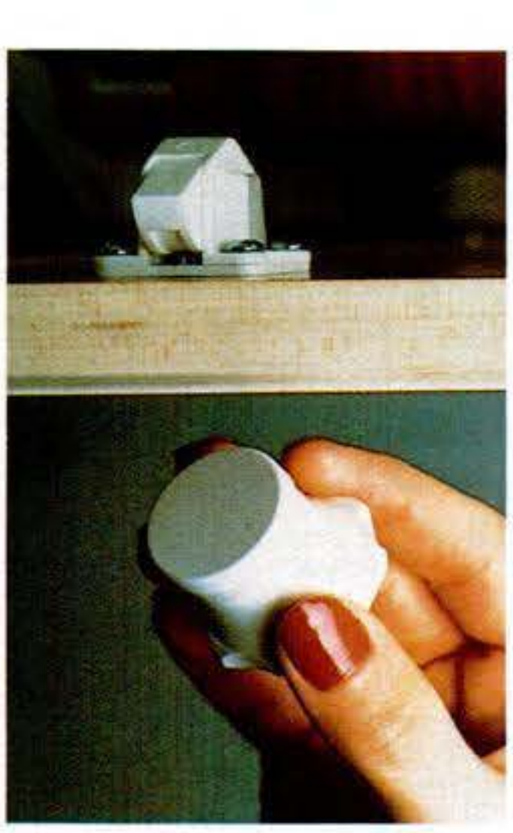
Nikon's N8008S 35mm autofocus camera is an augmented version of the top-of-the-line 1/8,000-second-shutter-speed N8008 for serious amateurs. The N8008S adds spot metering, which detects brightness within a 3.5mm circle centered in the viewfinder and autofocus tracking, which detects moving objects and calculates what will be the optimal focusing distance the instant the shutter begins to move. Price: about $899.

## COOL SUIT

The protective suits worn by fire fighters and other workers trap heat that can reach dangerously high levels. MSA's Core-Control "undersuit," threaded with 180 feet of plastic tubing, circulates cool water for two hours. A pump, its rechargeable nickel-cadmium battery, and a water reservoir strap to the waist, back, or torso. Price: about $1,700. MSA, Box 426, Pittsburgh PA 15230.

## POCKET MODEM

Forget about AC outlets—and batteries—with Hayes' Pocket Edition 2400 modem. The three-ounce 2,400-bit-per-second modem taps power from telephone lines and computer serial ports. Smartcom EZ communications software is included. Price: about $179.



## INVISIBLE LOCK

Keep curious children out of your cabinets with this locking device. It mounts on the inside of a door and is easily opened by adults with the pass of a magnetic key. No hardware is visible once the door is closed. One $8 key activates all catches, which cost about $8 each. The Woodworker's Store, 21801 Industrial Blvd., Rogers MN 55374.

## LOOK-CLOSE LENS

Because GEOscope detaches from its base, budding scientists can use it anywhere—even underwater. The $20 microscope has a 30x magnification, non-reflective glass lens, an internal light source, and flat and concave slides for viewing specimens. Super Science, 2315 N. Laurel Ave., Suite G, Upland CA 91786.

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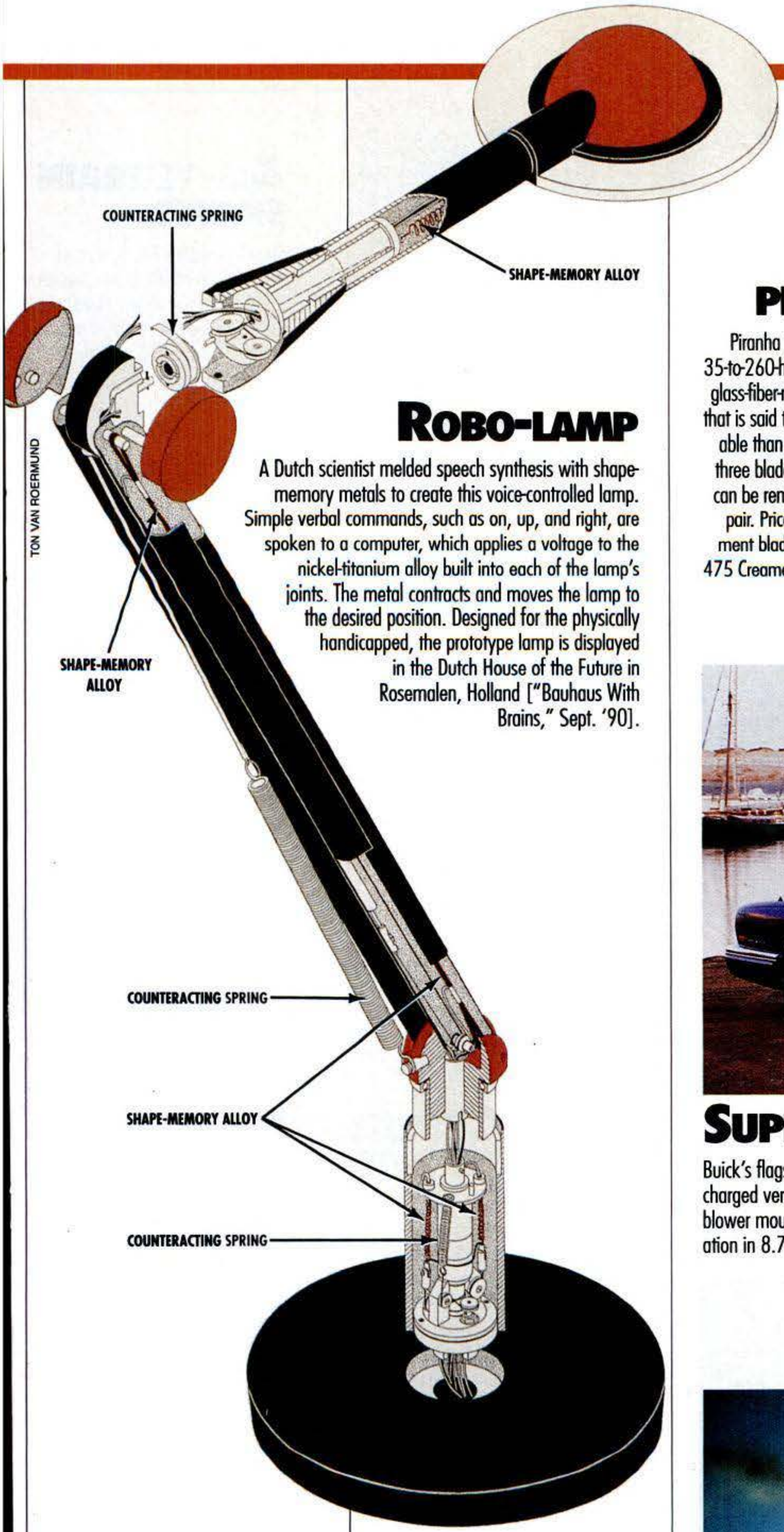



TON VAN ROERMUND

## ROBO-LAMP

A Dutch scientist melded speech synthesis with shape-memory metals to create this voice-controlled lamp. Simple verbal commands, such as on, up, and right, are spoken to a computer, which applies a voltage to the nickel-titanium alloy built into each of the lamp's joints. The metal contracts and moves the lamp to the desired position. Designed for the physically handicapped, the prototype lamp is displayed in the Dutch House of the Future in Rosemalen, Holland ["Bauhaus With Brains," Sept. '90].

## WIRELESS COMMAND CENTER

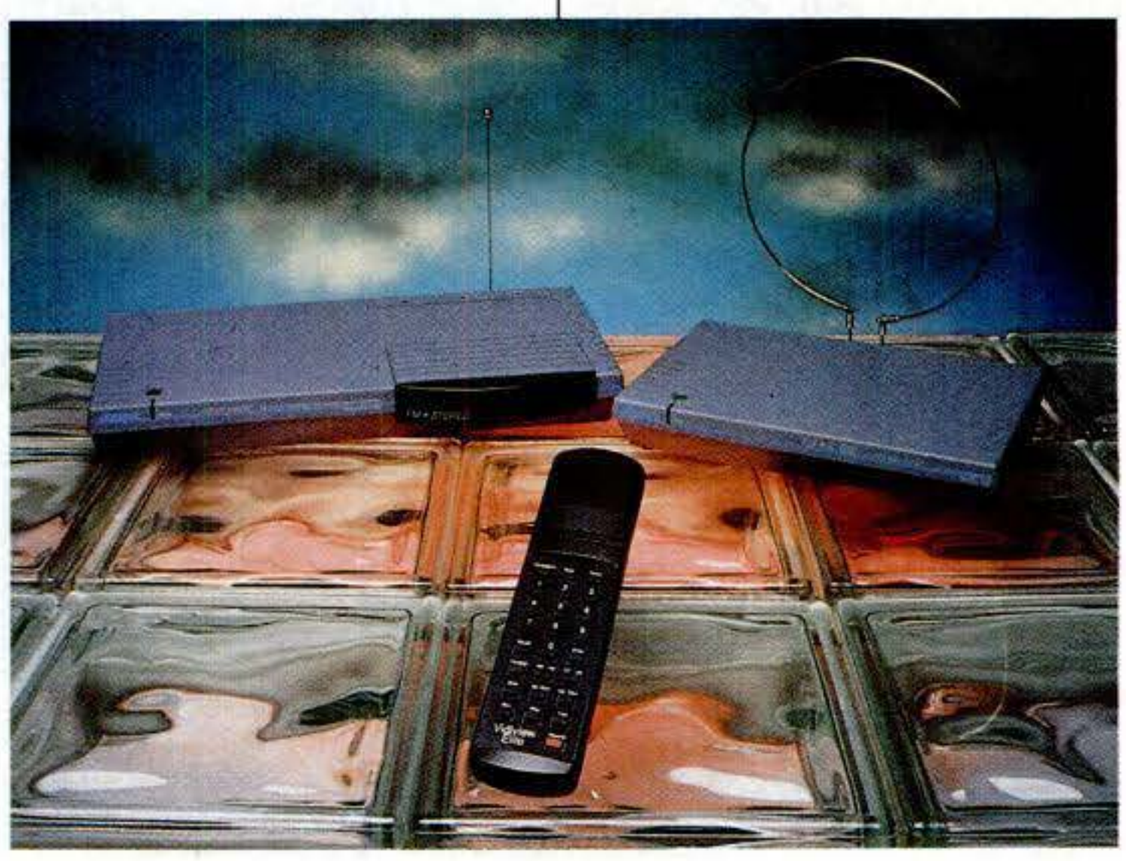
Wireless systems that broadcast pictures from a video source in one room to a television in another have a serious limitation: Most don't allow you to lower the volume, rewind a tape, or control other functions from a distance ["Room-to-room video," May '91]. But the $270 Vidi-View Elite has built-in remote capabilities, so you can operate up to four devices from 200 feet away. Vidicraft, 8770 S.W. Nimbus Ave., Beaverton OR 97005.

## EASY-FIX PROPELLER

Piranha Propellers, for boats in the 35-to-260-hp range, are made from a glass-fiber-reinforced nylon composite that is said to be lighter and more durable than aluminum. The propeller's three blades, available in six pitches, can be removed one at a time for repair. Price: $129; $20 per replacement blade. ICI Advanced Materials, 475 Creamery Way, Exton PA 19341.

## SUPERCHARGED!

Buick's flagship Park Avenue Ultra sedan will be offered in a limited-edition supercharged version later this year. The car's 3.8-liter V6, with a one-liter Roots-type blower mounted in the engine V, develops 205 hp, providing 0-to-60-mph acceleration in 8.7 seconds. Price is not yet set.





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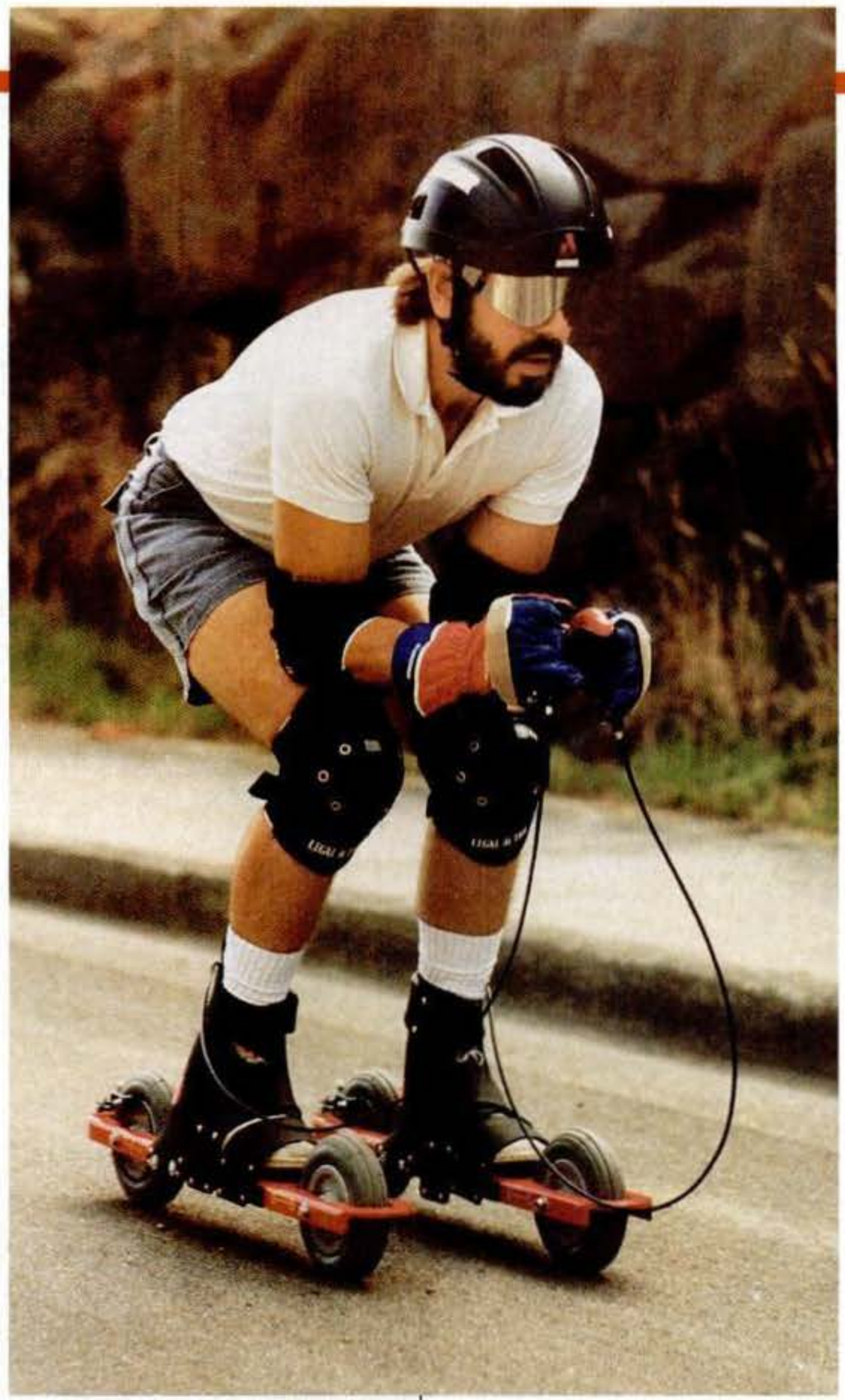
# WHAT'S NEW

## UNDERSEA CINEMA

Panasonic's PV-MC10 marine case holds the company's Palmcorder camcorders so you can film underwater movies at depths of up to 165 feet. The polyvinyl plastic shell has a 3/4-inch acrylic front plate and levers on the back that connect to the camcorder's power and pause buttons. A special gasket creates a watertight seal. The 7.2-pound case costs $500.

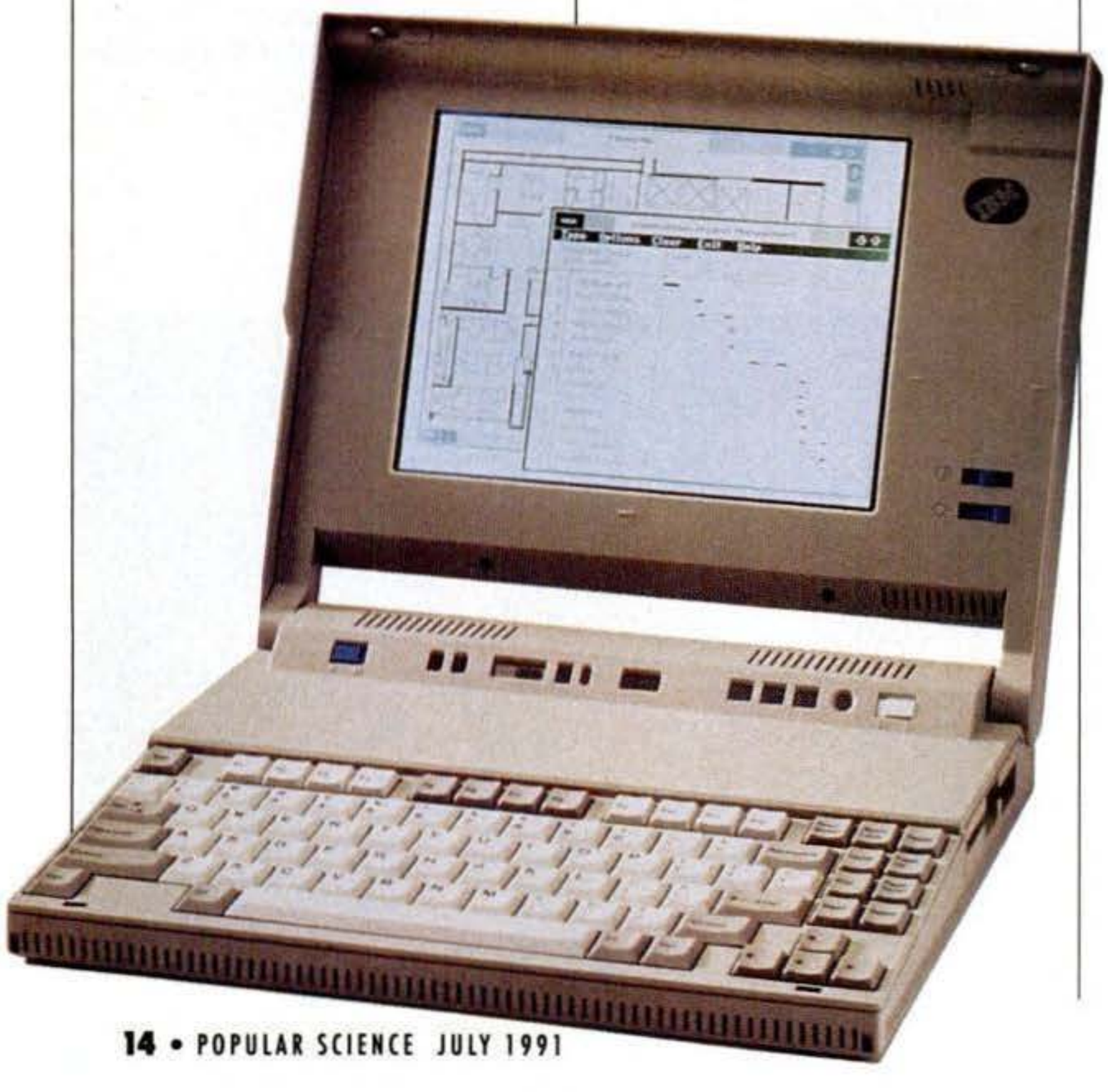


## ALL-TERRAIN SKATES

Strap Gateskate's PVC boots over your high-top athletic shoes, and you can skate on any terrain. Hand-held cable-operated caliper brakes attached to the seven-inch-high rear pneumatic tires let you control your speed or stop on target. The $375 skates, framed in lightweight fiberglass, are available in 28.25- or 29.25-inch lengths. Gateskate, 9716 122nd St. E., Puyallup WA 98373.

## CIRCUIT SENSOR

Check circuits safely with the Hot or Not AC Sensor. A bright red glow indicates the presence of electromagnetic and electrostatic fields generated by alternating current at 110 to 440 volts. The $20 battery-powered device need not contact the conductor to detect voltage. Hot or Not Marketing, Box 763, Lake Charles LA 70602-0763.



## BIG-KEYBOARD LAP-TOP

The full-size keyboard in IBM's 7.7-pound PS/2 Model L40 SX lap-top may offset the computer's bulk: 10.7 by 12.8 by 2.1 inches. The $5,995 portable has two megabytes of memory, a 60-megabyte hard-disk drive, a 1.4-megabyte floppy drive, and a 10-inch VGA display.



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# OWN YOUR FAVORITE MOVIES ON LASERDISC.

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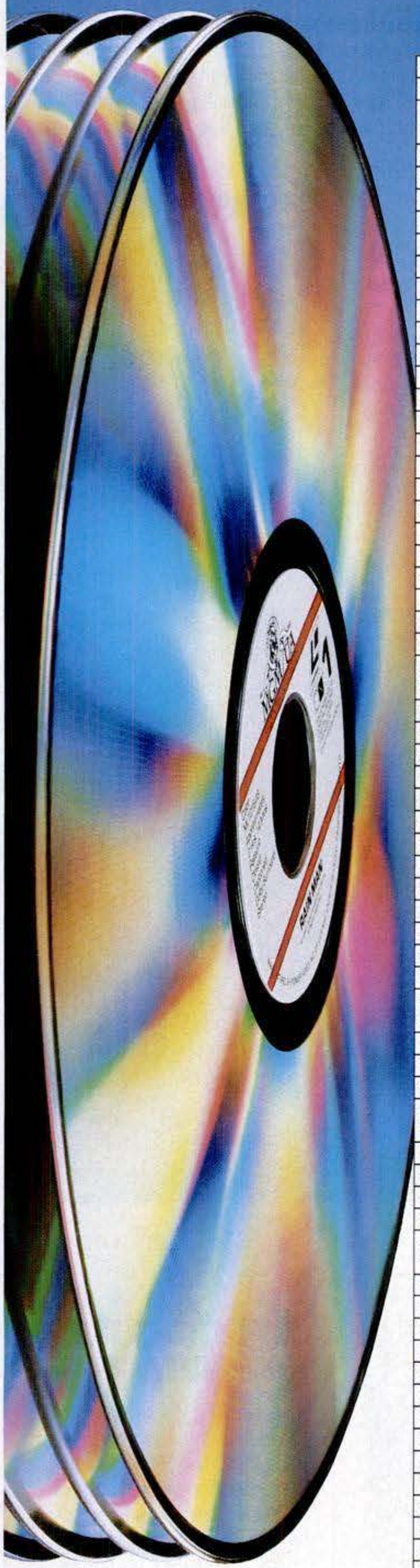

| | | |
|---|---|---|
| PRESUMED INNOCENT | | 9621002 |
| DIE HARD | ★ | 3676072 |
| BORN ON THE FOURTH OF JULY | ★ | 4891042 |
| BACK TO THE FUTURE | ★ | 2114092 |
| BACK TO THE FUTURE PART II | ★ | 9213042 |
| BACK TO THE FUTURE PART III | ★ | 4970082 |
| PREDATOR | | 3649012 |
| RETURN OF THE JEDI | ★ | 3547042 |
| MAN WHO WOULD BE KING | ★ | 0858032 |
| ROMANCING THE STONE | | 0894092 |
| BATMAN (1989) | ★ | 6425042 |
| THE BLUES BROTHERS | | 2117062 |
| E.T.: THE EXTRA-TERRESTRIAL | ★ | 6811062 |
| THE RIGHT STUFF | | 6043062 |
| ALIEN | | 0002082 |
| ALIENS | | 3609092 |
| 2001: A SPACE ODYSSEY | | 0025012 |
| DUNE | | 2111022 |
| EXCALIBUR | | 6021022 |
| BLUE VELVET | ★ | 5150072 |
| SCARFACE (1983) | | 2168042 |
| SUPERMAN: THE MOVIE | ★ | 0013052 |
| SUPERMAN II | | 6015002 |
| JAWS | | 1000082 |
| ROBOCOP | | 2350022 |
| ROBOCOP 2 | | 8040052 |
| AN AMERICAN WEREWOLF IN LONDON | | 7140062 |
| DIRTY DANCING | | 4955072 |
| F/X | | 6502002 |
| Q & A | | 3807092 |
| MAD MAX | | 7109052 |
| DOCTOR ZHIVAGO | ★ | 0026002 |
| THE COLOR PURPLE | ★ | 6301032 |
| BEN-HUR (1959) | ★ | 2603072 |
| RAIN MAN | | 2869062 |
| TANGO & CASH | ★ | 6474042 |
| LETHAL WEAPON | | 6308062 |
| LETHAL WEAPON II | ★ | 6427022 |
| HARD TO KILL | | 9535052 |
| BLAZING SADDLES | | 0012062 |
| NATIONAL LAMPOON'S ANIMAL HOUSE | | 2115082 |
| FIDDLER ON THE ROOF | ★ | 0551032 |
| ONCE UPON A TIME IN AMERICA | | 6058082 |
| THE DEER HUNTER | ★ | 2124072 |
| THE DAY THE EARTH STOOD STILL | | 0576042 |
| SPARTACUS | | 2108072 |
| AROUND THE WORLD IN 80 DAYS | | 6036052 |
| THE AFRICAN QUEEN | | 0511022 |
| AMERICAN GRAFFITI | | 2113002 |
| BUTCH CASSIDY AND THE SUNDANCE KID | | 0517062 |
| THE EXORCIST | | 6003042 |
| THE BIBLE | ★ | 0747082 |
| FIELD OF DREAMS | | 9203062 |
| ROAD WARRIOR | | 6028052 |
| BLUE STEEL (1990) | | 6965002 |
| DARKMAN | | 4981052 |
| HOW THE WEST WAS WON | ★ | 2669082 |
| MAGNUM FORCE | | 6090082 |
| NEXT OF KIN | | 6472062 |
| THE LAND BEFORE TIME | | 5822052 |
| OUT OF AFRICA | | 2131082 |
| BEETLEJUICE | | 6330082 |
| SUDDEN IMPACT | | 6146022 |
| DIRTY HARRY | | 6017082 |
| THE BIRDS | | 1027072 |
| DANGEROUS LIAISONS | ★ | 6387002 |
| BIRD ON A WIRE | ★ | 4973052 |
| BULL DURHAM | | 2360002 |

## 3 LASER DISCS $1 EA.

SEE DETAILS BELOW.

Die Hard 2*
0418062

The Wizard Of Oz *
(Anniversary Edition)
2941082

Total Recall
2276032

The Sound Of Music *
0039052

Star Wars *
0564082

An American Tail
2184042

Empire Strikes Back*
0910092

Patton*
0043092

The Abyss*
8811022

Here's a great way to build a collection of your favorite movies–on laserdiscs! Just write in the numbers of the 3 laserdiscs you want for $1.00 each, plus shipping and handling. In exchange, you simply agree to buy two more laserdiscs in the next year, at regular Club prices (currently as low as $29.95, plus shipping and handling)–and you may cancel membership at any time after doing so.

Every four weeks (up to 13 times a year), you'll receive a Club mailing, reviewing our Director's Selection–plus scores of alternate choices, including many lower-priced laserdiscs. And you may also receive Special Selection mailings up to four times a year. (That's up to 17 buying opportunities a year).

You buy only what you want–when you want it! If you want the Director's Selection, do nothing–it will be sent automatically. If you'd prefer an alternate selection, or none at all, just mail the response card always provided by the date specified. And you'll always have 14 days to decide; if not, you may return the selection at our expense.

There's a money-saving half-price Bonus Plan. If you continue your membership after fulfilling your obligation, you'll be eligible for our Bonus Plan. With each selection you buy at regular Club price, the plan currently allows you to take another selection of equal value or less at 50% off...so you'll continue to save money for as long as you remain a member.

And there's a 10-day risk-free trial. We'll send details of the Club's operation with your introductory package. If not satisfied, return everything within 10 days for a full refund and no further obligation.

**For fastest service, use your credit card and our toll-free number. Call 24 hours a day:**

**1-800-538-2233**

**Columbia House LASERDISC CLUB**

Dept. T4W P.O. Box 1112 , Terre Haute, Indiana 47811-1112

Yes, please enroll me under the terms outlined in this advertisement. As a member, I need buy only 2 more selections, at regular Club prices, within the coming year.

**Send me these 3 laserdiscs for $1.00 each** plus $1.50 each shipping and handling(total $7.50)

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*Letterbox

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# WHAT'S NEW

## HANDY COMPUTING POWER

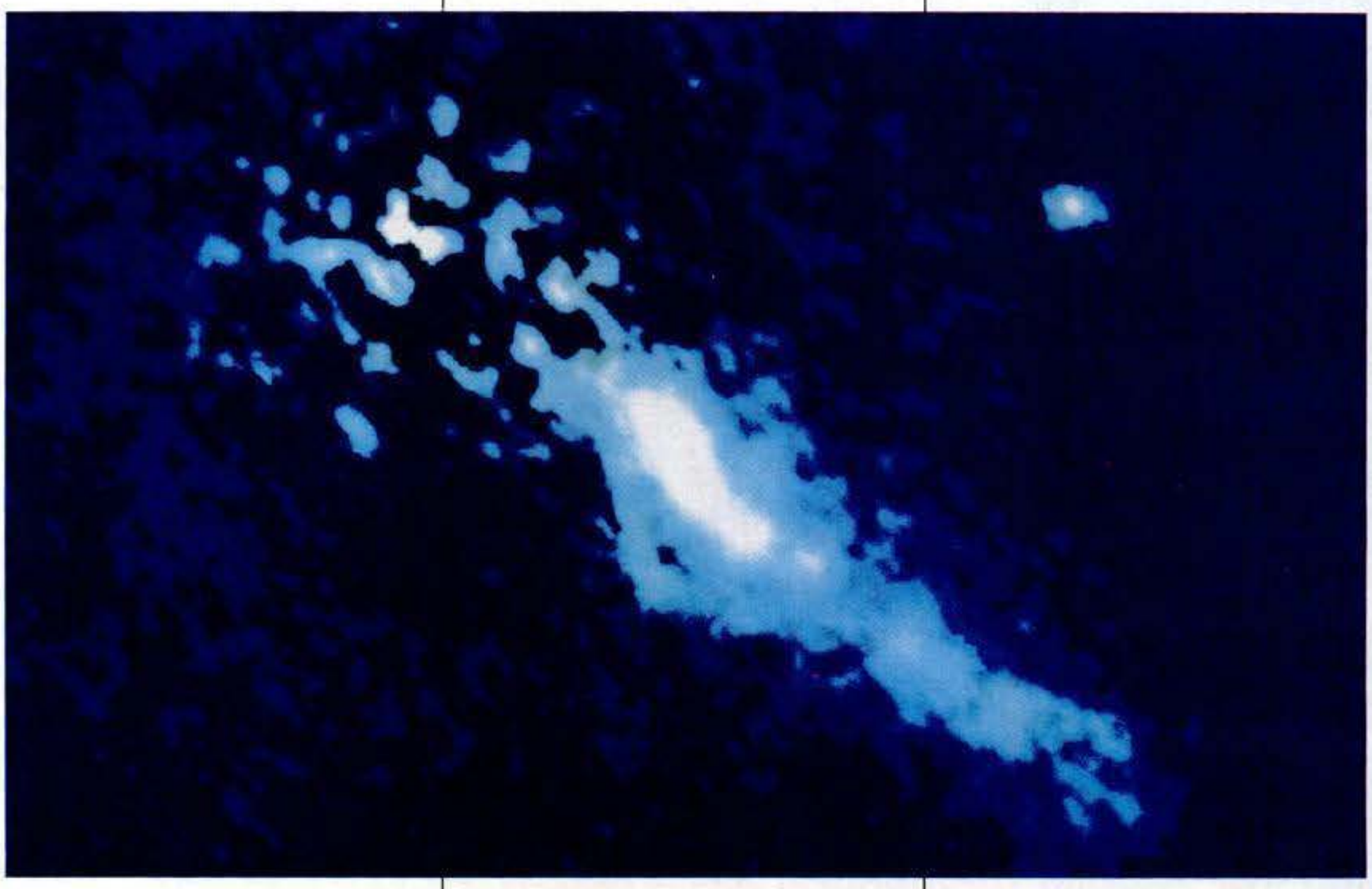
NEC combines a personal computer and an electronic diary in its Handy 98 portable PC. The 2.4-pound unit measures 9.2 by 5.8 inches and is 1.4 inches thick. Software can be loaded from an internal memory card slot or from an optional docking station with a 3.5-inch drive. Because the operating system and software are compatible with Japanese versions, NEC plans sales exclusively in Japan.

## CLIP-ON SAFETY

Clip VistaLite's VL-300C to your clothing, bicycle, almost anywhere and the unit's flashing LED will be visible up to 2,000 feet away. It runs for 300 to 500 hours on two AA batteries. Price: about $17. Vistalite, Inc., 2950 Old Tree Dr., Lancaster PA 17603.

## GALACTIC STREAM

Ejected from the core of a galaxy 270 million light-years away, this stream of electrons, called an optical jet, is unusually twisted and knotted. The picture may help astronomers understand the roles of optical jets and magnetic fields in galaxies. Observed by the Faint Object Camera aboard the Hubble Space Telescope, the ultraviolet light image was altered to minimize the spherical aberration produced by Hubble's primary mirror.



## PRIVATE ENTRANCE

The Staywell 21 Electronic Cat Door emits a radio signal that is interrupted by a "key" collar worn by your pet, releasing the latch. The $150 door can be locked or set for one- or two-way passage. Heath Co., Box 1288, Benton Harbor MI 49022.

## SPECTACULAR VIEWER

Hate removing your glasses to use binoculars? The wide-angle GlassesOn binoculars have thick-rimmed rubber eyecups contoured to fit the shape of your lenses, plus optics adjusted for the greater distance between the ocular lens and your eye. The binoculars have a 7x magnification and cost $198. Jason Empire, 9200 Cody, Box 14930, Overland Park KS 66214-3259.



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# Clean getaways this summer start at Kmart.

**◄Car Care Tip►**

*Waxing at least twice a year helps prevent oxidation and road grime buildup, and protects your car's finish in tough weather.*

**A Liquid Crystal.** Cream and liquid wax, 16-oz. size.
Your choice . . . . . **10.97**

**B Simple Green.** Multi-purpose cleaner, 24 fl. oz. . . . . **3.97**
Economy size, 67 fl. oz. . . . . **6.47**

**C Espree** all-purpose or wire wheel cleaner, 32-oz., or Bleche-Wite whitewall cleaner, 32-oz. economy size.
Your choice . . . . . **1.99**

**D Turbo Wash Pulsator.** Power washer with pulsating action for better cleaning. Ideal for cars, vans and RVs. Complete with Soft Suds, 16-oz. . . . . **7.97***
***After $5.00 mail-in rebate. See stores for details.**

**E Armor All Protectant.**
Economy 32-oz. refill with 4-oz. cleaner and wash . . . **5.97**
Armor All Car Wash, 40-oz. . . . . **3.97**

**On sale June 23-July 6, 1991, at most U.S.A. Kmart stores.**

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## *Save on the perfect soundtrack for summer roadtrips.*

**A** **Sparkomatic** AM/FM Compact Disc Player with 18-program tuner, scan, fader, 25-watt output.
Model SR600 . . . . . **249.00**

**B** **Sparkomatic** AM/FM Stereo Cassette Player w/locking F.F., 5-band equalizer, 4-way balance/fader. Local/distance switch.
Model SR38 . . . . . **69.00**

**C** **Sparkomatic** AM/FM Stereo Cassette Player with Speakers. Dual cone speakers complete with wiring. Simple installation. Fits many cars and trucks. While quantities last.
Model C45BP . . . . . **49.00**

**D** **Cobra** Emergency CB Radio 39 Plus. Instant emergency communication for car or truck. 4-watt two way radio that operates on all 40 CB channels . . . . . **49.00**

**E** **Sparkomatic** Three-Way 6x9″ Speaker Set. Handles up to 160-watt peak system power. Deck mounts.
Model SK693 . . . . . **24.00** pr.

**F** **Cobra** Compact CB Radio. With squelch, digital readout, LED signal strength meter. Instant emergency channel 9. Model C20 . . . **49.00**

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### ◄Car Audio Tip►

*One of the best ways to improve the sound in your car is to add an amplifier/equalizer. Even at low volume, the added power of the amplifier provides cleaner, crisper sound.*

**A** **Audiovox** Amplifier/Equalizer. 50-watt equalizer w/dual power meters. LED slide controls, built-in fader.
Model AMP 785 . . . . . **49.00**

**B** **Audiovox** Carpeted Portable Speaker System. Handles up to 150 watts. 8″ woofer, 3½″ tweeter, 2″ sub bass ports.
Model VB-2 . . . . . **99.00** pr.

**C** **Jensen** ETR Stereo Cassette w/auto reverse, 18 presets, seek and scan, tone and fader. 10 watts.
Model CS4500 . . . . . **119.00**

**D** **Sony** ETR Stereo Cassette Player w/auto reverse, 18 presets, fader control, w/clock.
Model ESR-11 . . . . . **139.00**

**E** **Whistler** Radar Detector. Three segment LED readout array for X and K band monitoring. City/Highway mode switch and indicator. One year warranty.
. . . . . **59.00**
Model numbers vary. WH280 or WH225, both 59.00. Not available in CT and VA.

The quality you need, the price you want.

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# *Hurry in for made-in-the-shade savings.*

**◄Car Care Tip►**

*Besides reducing the temperature inside your parked car, sunshades can help prevent your car's dash and front seat upholstery from prematurely aging and fading due to the damaging rays of the sun.*

**25% off our everyday low prices on Sunshades and Auto Fans.**

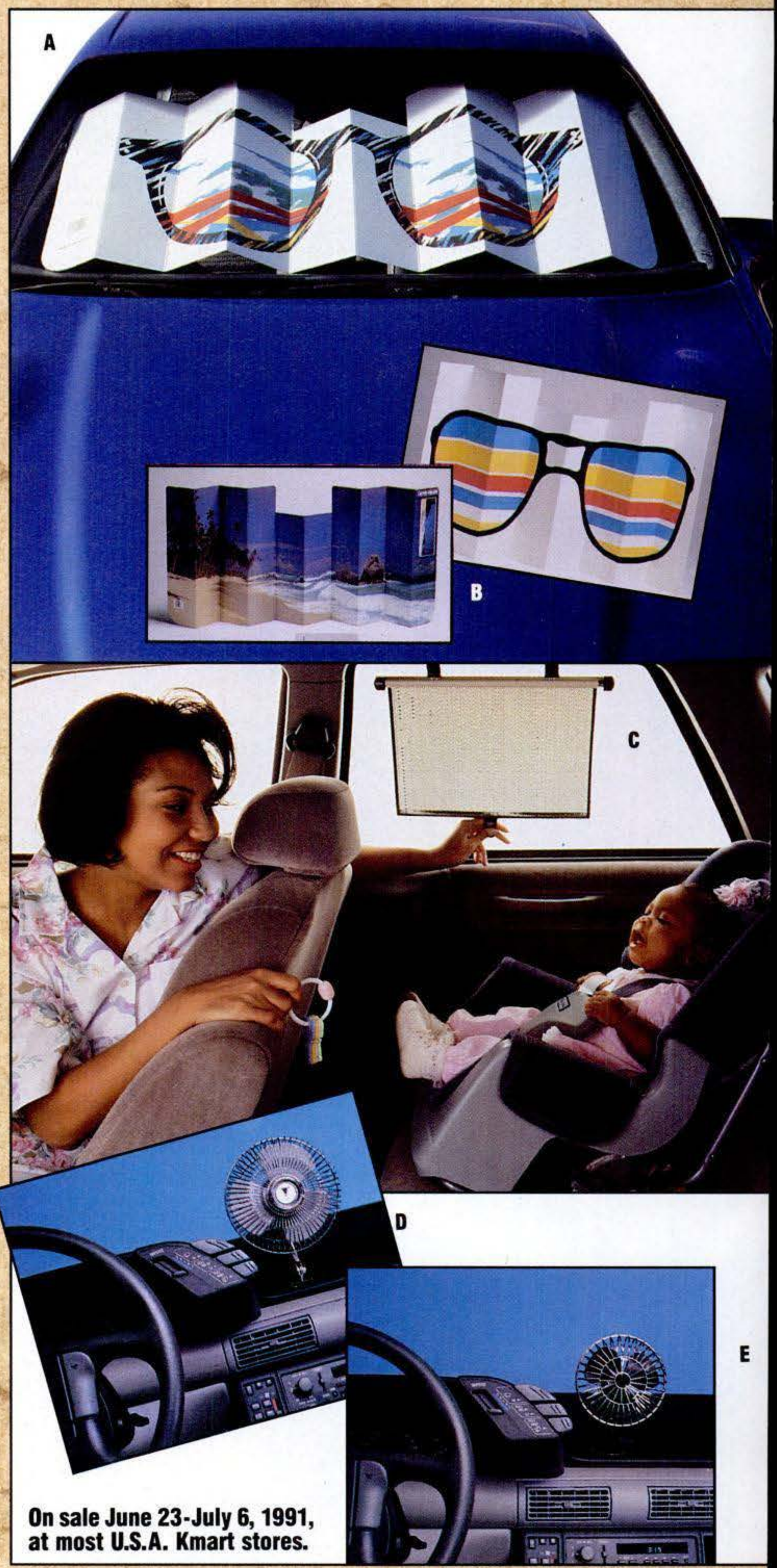
**A Folding Sunshade.** Folding auto sunglasses shade, protects dash, seat and steering wheel from damaging sun rays . . . . . **1.47**

**B Jumbo Folding Sunshade.** Oversize to fit pick-ups or vans. Assorted colors to choose from . . . . . **2.01**
**Poster Sunshade** . . . . . **1.85**

**C Auto Roller Shade.** Deluxe Glare Guard auto window shade. Fits all cars, vans and trucks. Retractable roller action. Installs quickly without tools . . . . . **2.22**

**D 6" – 12-Volt Car Fan.** Handy for car, RV or van. 12-volt system . . . . . **11.97**

**E Auto Mini-Fan.** 4" fan with oscillating feature. Chrome-plated bottom w/suction cup. Assorted colors to choose from . . . . **5.22**

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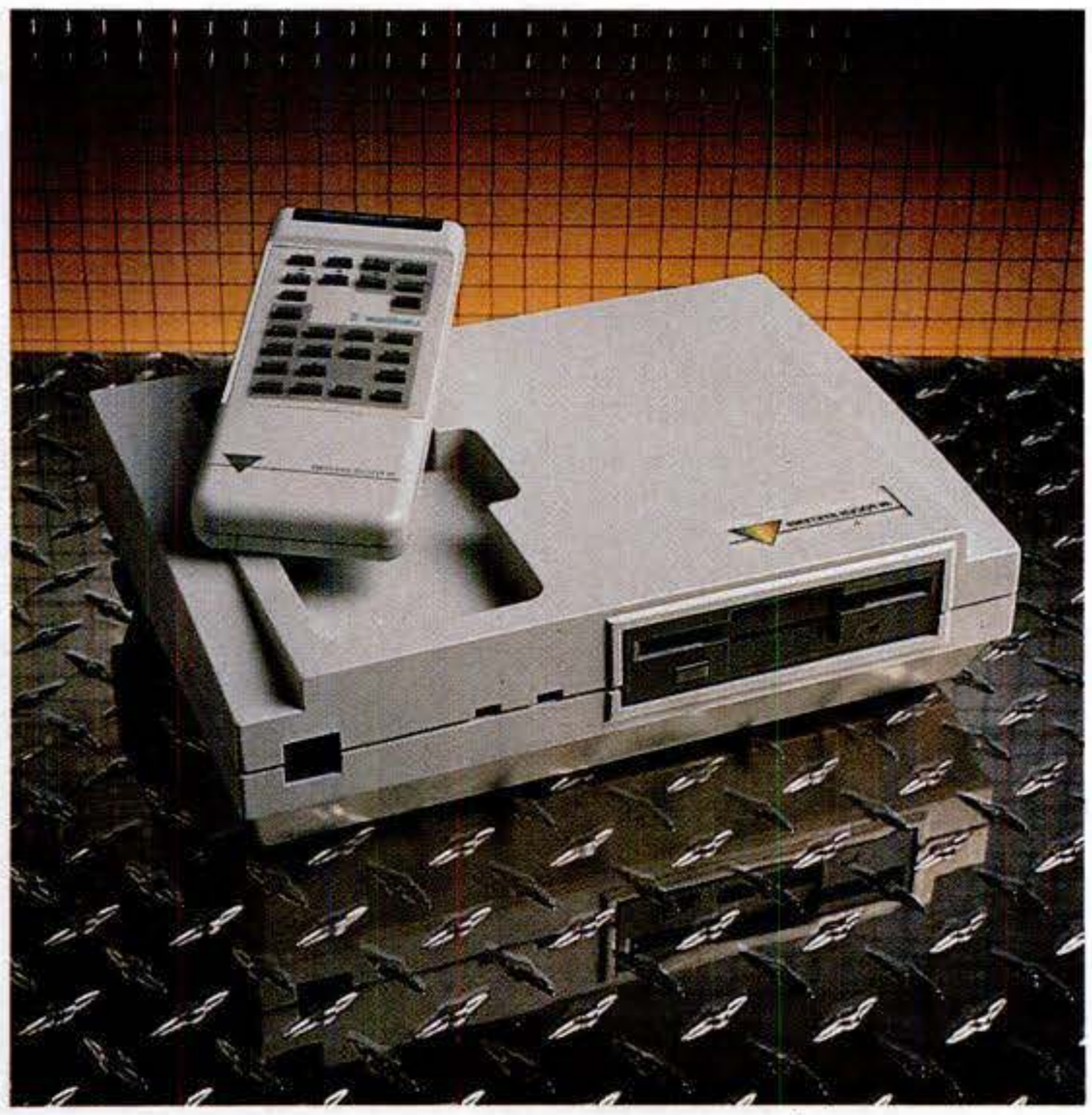
# WHAT'S NEW

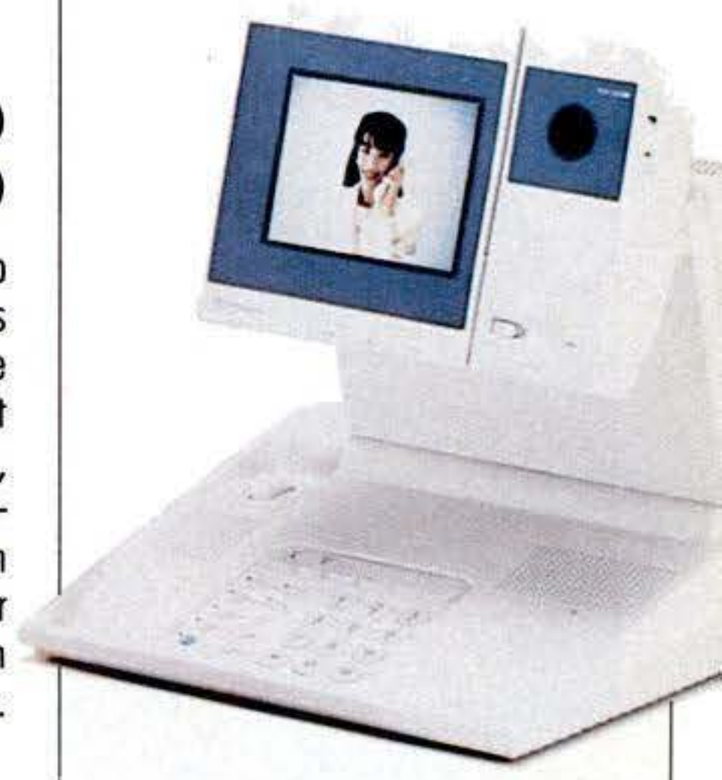


## TRAVELING LIGHT

Connect the LiteShow II portable presentation system to your computer and use the "grab" function on its remote control to capture graphics on a 3.5-inch disk. Then you don't have to haul a computer along to make your pitch. Simply plug the 3.7-pound device into a color LCD projection panel. In Focus Systems, 7770 S.W. Mohawk St., Tualatin OR 97062.

## VOICE AND VIDEO

Hitachi's first all-in-one desktop videophone, the HV-100, enables two-way communication of voice and color motion video. Document data, input via the built-in keyboard, can also be transmitted. The videophone has a five-inch high-resolution liquid-crystal display for clear viewing. It will be available in Japan later this year.

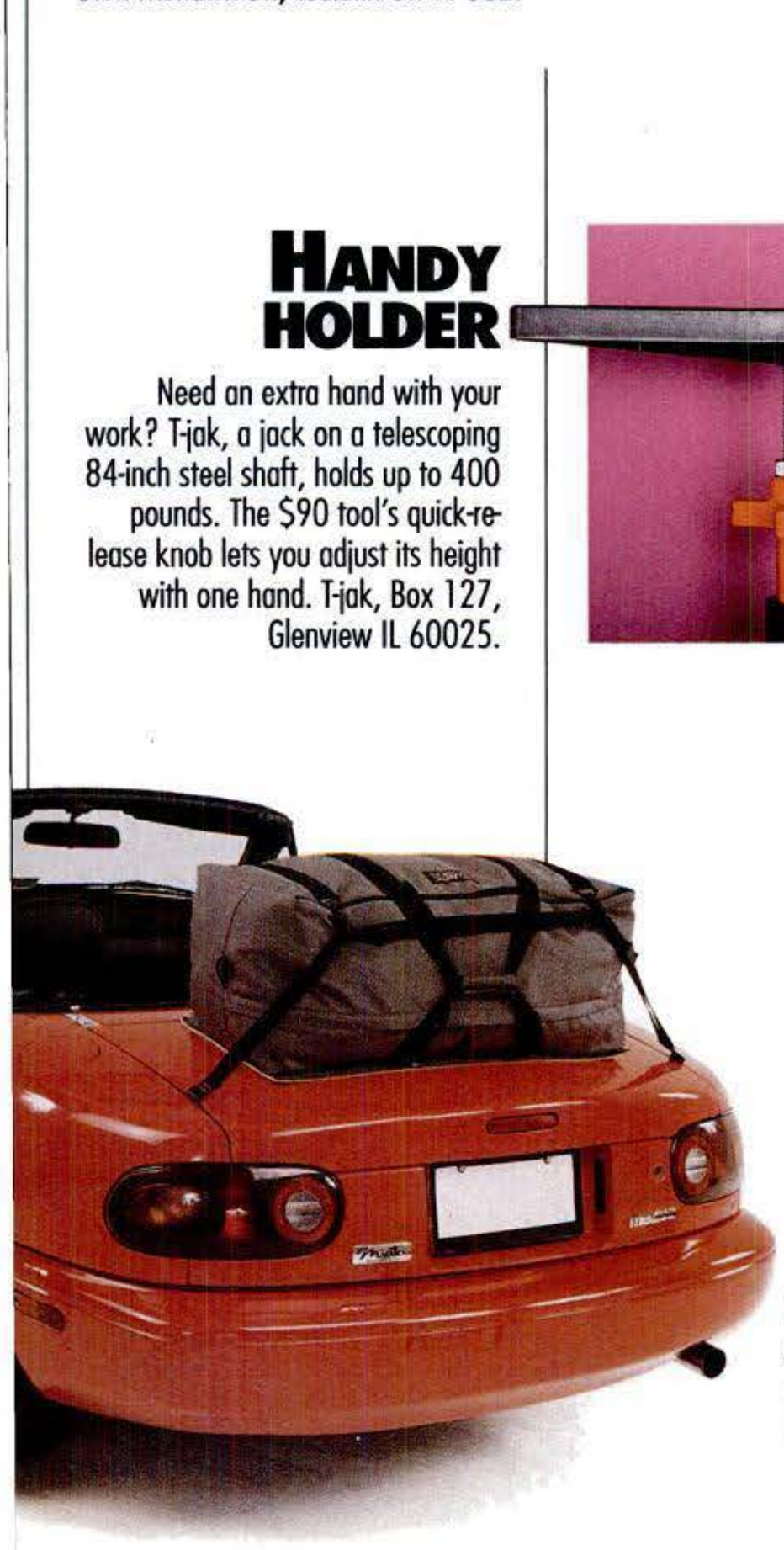


## HANDY HOLDER

Need an extra hand with your work? T-jak, a jack on a telescoping 84-inch steel shaft, holds up to 400 pounds. The $90 tool's quick-release knob lets you adjust its height with one hand. T-jak, Box 127, Glenview IL 60025.

## LIGHTWEIGHT 35

Canon's 35mm Rebel S camera now includes a built-in pop-up electronic flash. At less than 16 ounces, it's the lightest 35mm SLR available, says Canon. The camera is offered in a kit including a new EF 35-105mm f/4.5-5.6 zoom lens, a carrying case, and a watch. Price: $700.



## SPORTS LUGGAGE

No luggage rack needed; this sports car luggage mounts directly on your car's trunk. Maker Atlantic Design says it's weatherproof and won't damage the car finish. The $160 standard-size bag (left) has a capacity of 2.93 cubic feet and comes with a mounting pad and straps; a 5.33-cubic-foot bag costs $180. Atlantic Design, 977 Seminole Trail, Suite 308, Charlottesville VA 22906.



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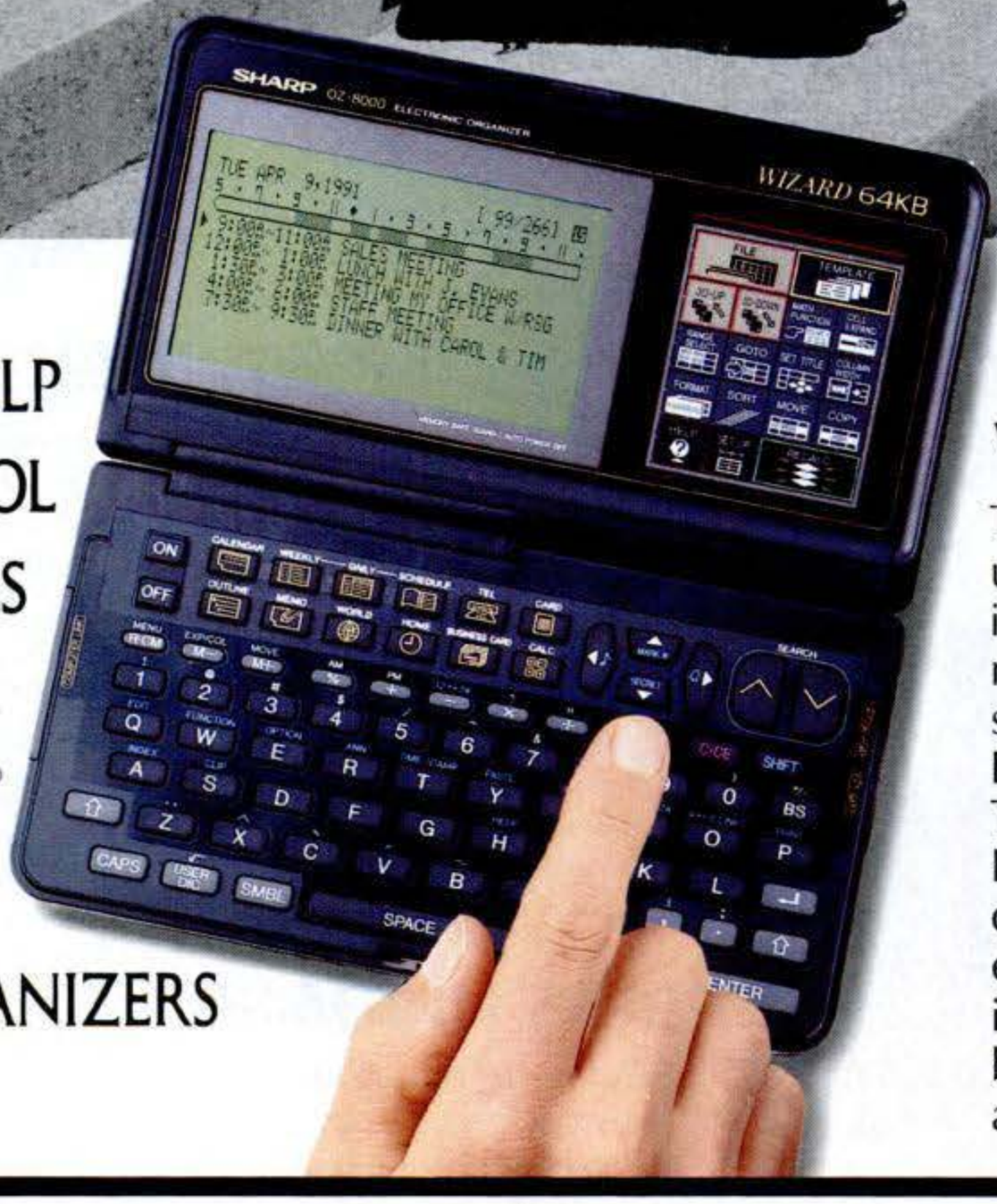
# WIZARD®


SHARP OZ-8000 ELECTRONIC ORGANIZER
WIZARD 64KB
TUE APR 9,1991
9:00A 11:00A SALES MEETING
12:00P 1:00P LUNCH WITH J. EVANS
1:30P 5:00P MEETING MY OFFICE W/RSG
4:00P 6:00P STAFF MEETING
7:30P 9:30P DINNER WITH CAROL & TIM

## NOTHING CAN HELP YOU TAKE CONTROL OF ALL THE DETAILS OF YOUR BUSY LIFE LIKE THE WIZARD® AND ZQ SERIES ELECTRONIC ORGANIZERS FROM SHARP.

## INTRODUCING THE WIZARD® 8000.

The OZ-8000 is a powerful yet uncomplicated computer that fits in the palm of your hand. Our new "Help" key provides step-by-step instructions for each functio Eleven built-in features include a Text Outliner and Business Card File. A raised keyboard and 40 character, 8 line display make it easy to enter, sort, and retrieve information quickly. You can eve back up your data in seconds on an optional memory card.

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# THE POWER TO ORGANIZE YOUR BUSINESS AND PERSONAL LIFE.

**ZQ-2000**
12 Character x 4 line display.
Exchanges data with other Sharp organizers.
16K memory.
Shirt pocket sized.

**ZQ-2200**
12 Character x 4 line display.
Exchanges data with other Sharp organizers.
32K memory.
Shirt pocket sized.

**ZQ-5000**
16 Character x 8 line display.
Shirt pocket sized.
9 built-in functions.
32K memory.

**ZQ-5200**
16 Character x 8 line display.
Shirt pocket sized.
9 built-in functions.
64K memory.

**WIZARD OZ-7000**
16 Character x 8 line display.
Software expandable.
32K memory.
(Built-in Schedule function shown.)

**WIZARD OZ-7200**
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Software expandable.
64K memory.
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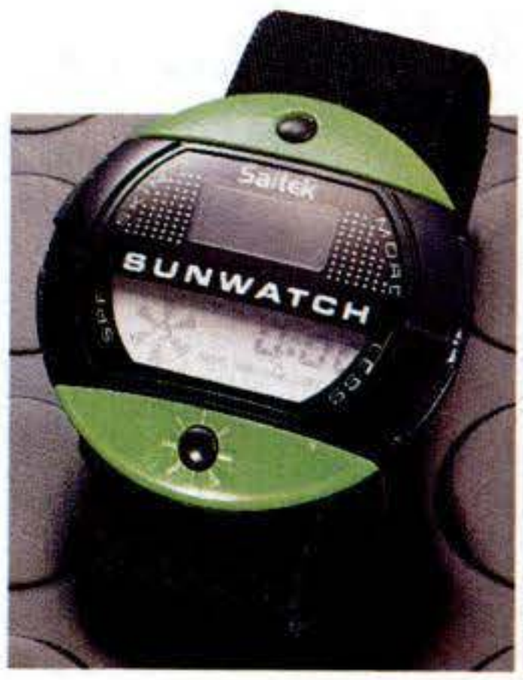
# WHAT'S NEW

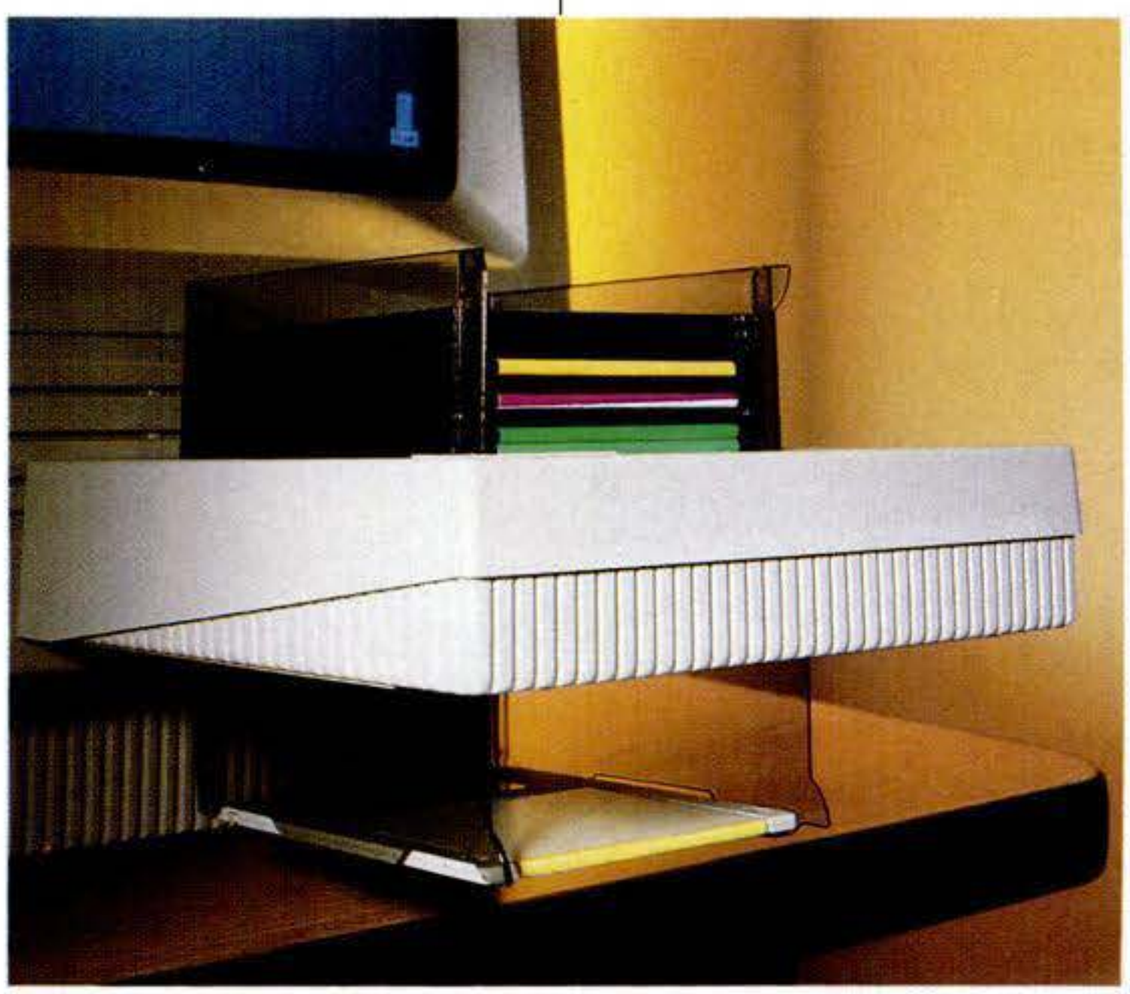
## BURN METER

When you enter your skin type and the rating of your suntan lotion, Sunwatch measures the strength of solar UVB rays and calculates how long you can safely stay in the sun. The time remaining appears on the LCD screen; touch a button, and it displays the time. Price: $59. Saitek Industries Ltd., 2291 W. 205th St., Suite 101, Torrance CA 90501.




## ALL THE ANGLES

Need a precise pitch reading? Excalibur's Angle Finder levels have a rotating spirit vial encased in a two-part protractor scale that's accurate to within half a degree. Available in 24-, 36-, 48-, and 72-inch sizes, the aluminum levels are priced from $27 to $63. Excalibur Hand Tools, 10621 S. Lockwood St., Oak Lawn IL 60453.



## MAC FEEDER

Attach Jukebox Five to your Macintosh computer and stack up to 15 disks for automatic formatting, erasing, hard-disk backup, or copying. The $99 device comes with an AC adapter or can be powered by four AA batteries. Fifth Generation Systems, 10049 N. Reiger Rd., Baton Rouge LA 70809-4562.

INTERNATIONAL NEWS SERVICE

## EMERALD CITY

A city may someday be enclosed by this monolithic glass structure, say Japanese designers. More than 6,600 feet high and covering nearly 2,000 acres, it would be constructed with hollow girders and include offices, hotels, leisure facilities, and 249,000 housing units. Designers speculate it would take seven years to construct, at a cost of 88 trillion yen (about $642,329,600,000).

## CDs TO GO

Retrofitting your car with a CD player is as easy as installing Audioline's CD 400 Compact Disc Auto Changer. Because it operates through the FM radio, the CD 400 needs no added controller. The changer, with a six-disc magazine, mounts in the trunk and operates via a small command unit. Audioline AG, Freiburgstrasse 572, 3172 Niederwangen/ Bern, Switzerland.



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*MSRP Ford F-150 XLT Lariat (auto. trans.) vs. comp. equipped Chevy C1500. **The Complete Small Truck Cost Guide, 1991, IntelliChoice® Inc., F-150 and C1500 base models with selected options and most popular engines. Actual oper. costs and resale prices may vary. "Best-Built" claim based on an average of consumer-reported problems in a series of surveys of all '81-'90 lt. truck models designed and built in North America. Sales by Division.

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# Science Newsfront

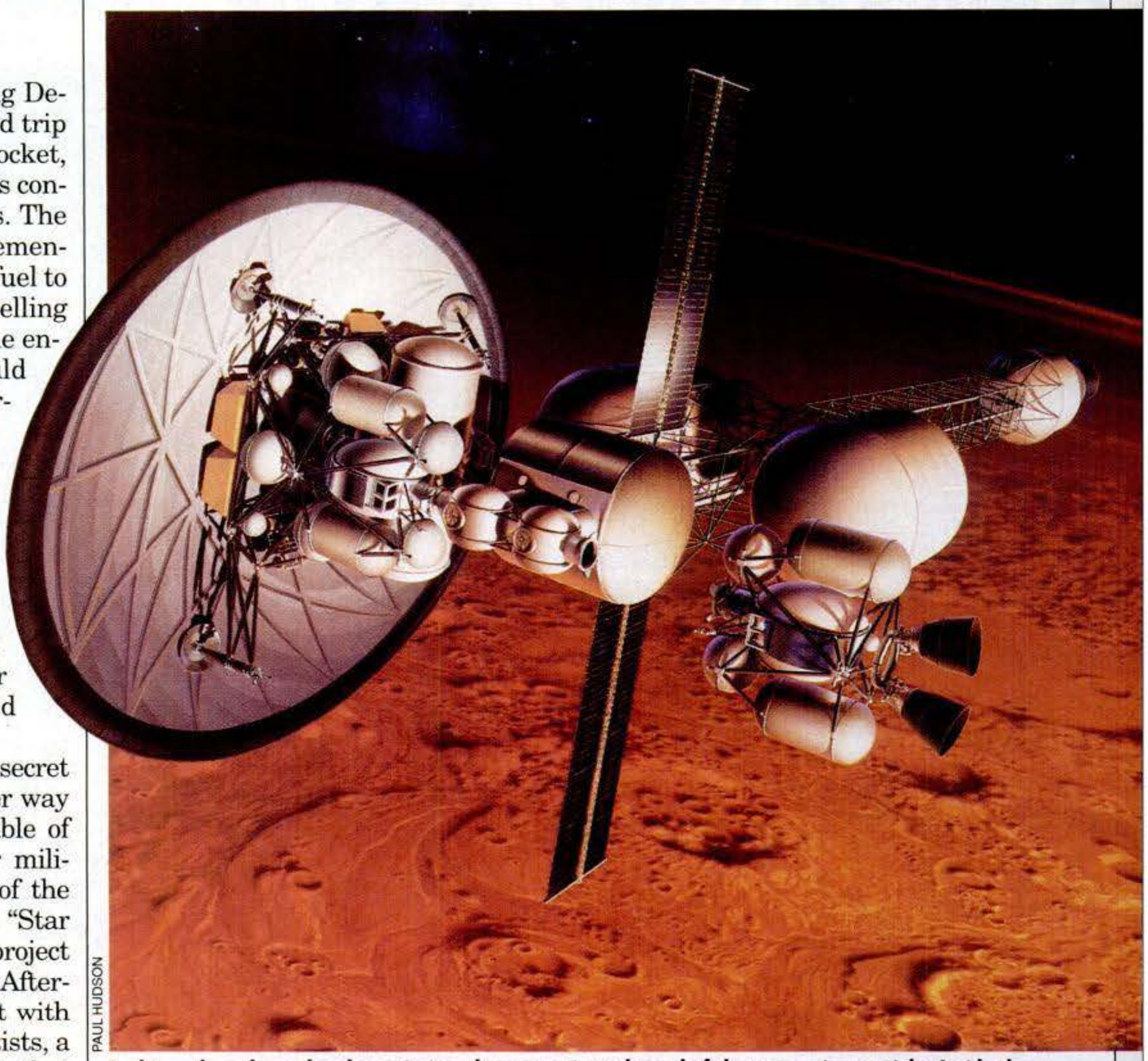
**Edited by DAWN STOVER**

## Nuclear rocket for Mars?

The power source urged by Boeing Defense & Space Group for a manned trip to Mars is a nuclear-thermal rocket, like the one seen here in an artist's concept of a spacecraft orbiting Mars. The rocket's reactor would produce tremendous thrust by heating hydrogen fuel to high temperatures and then expelling it at very high velocity through the engine's nozzle. Two landers would transport astronauts to the Martian surface.

Boeing made its recommendation to NASA after considering some 70 different propulsion systems. The method chosen would enable Earth-to-Mars trips of between 250 and 450 days, considerably faster than with chemical propulsion. Some of the other methods Boeing studied would have taken 1,000 days.

Meanwhile, at the Pentagon, a secret project called Timberwind is under way to develop a nuclear rocket capable of lifting heavy weapons and other military payloads into orbit as part of the Strategic Defense Initiative—the "Star Wars" program. The classified project was revealed in April by Steven Aftergood, a defense and space analyst with the Federation of American Scientists, a private group in Washington, D.C., that has consistently opposed the Star Wars anti-missile program.—*Arthur Fisher*



PAUL HUDSON

**In this nuclear-thermal-rocket painting, the reactor is at the end of the truss spine at right. Inside the aero-brake disc at the front is one of two landing vehicles; the other is shown returning from the surface.**

## Comfortably numb

Your teeth are the least of your dentist's worries; they can be fixed. But your psyche is another matter. According to the American Dental Association, more than 45 million Americans postpone visiting their dentists (or shun them altogether) because of anxiety. Part of that fear centers on the dentist's hypodermic needle.

Now a drug-delivery company has developed a flexible anesthetic pad that could numb areas about to be drilled or cleaned. Noven Pharmaceuticals in Miami claims that its product will adhere to the gums or lip, making shots unnecessary for aggressive dental cleaning and small fillings. "We anticipate a nice numbing effect," says Noven's Mitchell Goldberg. "If this could eliminate the problem and the pain, it would be good for the dentist and good for the patient."

The Noven pad is years away from widespread use. But federal approval might be expedited because the product will contain an anesthetic already licensed by the U.S. Food and Drug Administration. Whether the newfangled pad will deaden nerve endings as well as the old-fashioned needle remains to be seen. Blood circulating through the tissue of the mouth tends to disperse drugs quickly, and Noven hasn't disclosed how it plans to confine the anesthetic to the drilling area. Anesthetic injections contain a hormone that constricts blood vessels, but incorporating the hormone in a pad would prevent the anesthetic from reaching the tissue.—*Mark D. Uehling*

## Eclipse viewing

July 11 will see the last total solar eclipse visible in some part of the United States until 2017. The path of totality—the eerie blocking of the sun's whole disc by the moon—will sweep across part of the island of Hawaii, Baja California and other parts of Mexico, and areas in Central and South America. A partial eclipse will be visible, weather permitting, in the rest of the United States, except in Alaska and Maine.

Jay M. Pasachoff, director of the Hopkins Observatory at Williams College in Williamstown, Mass., and an expert on solar astronomy, cautions that only during the total phase, lasting several minutes, is it safe to look at the sun directly (or peer at it through a camera viewfinder) without appropriate eye protection, such as a special filter that admits only $^{1}/_{100,000}$ of the light striking it. Gelatin filters do not block infrared and so are unacceptable. You can make a solar filter by exposing black-and-white film to sunlight, then developing it to maximum density; use one or two thicknesses of the exposed film. Even with such a filter, take only quick looks; don't stare. Using a



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pinhole camera is both easier and safer.

For details on photographing both partial and total phases, consult the 1990 edition of *A Field Guide to Stars and Planets*, by Pasachoff and D. H. Menzel, published by Houghton Mifflin.—*Arthur Fisher*

## Hubble's eyeglasses

To correct the Hubble Space Telescope's vision, NASA officials are considering a prescription that would cost at least $50 million. Because Hubble's primary mirror has a spherical aberration, the raw images it sends to Earth are blurred ["The Trouble with Hubble," Oct. '90].

NASA's proposal calls for replacing one of Hubble's six scientific instruments with COSTAR, the Corrective Optics Space Telescope Axial Replacement. COSTAR is like a set of eyeglasses, but it would restore Hubble's eyesight using mirrors rather than lenses. The mirrors, each the size of a postage stamp, are arranged in five pairs. In each pair, a flat mirror bounces incoming light off its partner—an overly concave mirror that compensates for the flaw in the primary mirror, which was ground too flat.

Astronauts hope to install COSTAR, as well as an improved Wide Field & Planetary Camera with internal corrective optics, during a shuttle mission tentatively scheduled for June 1993. At the same time, they'll probably replace Hubble's solar panels. The panels vibrate when they pass in and out of Earth's shadow, preventing the telescope from pointing properly.

**This view of Mars is a composite of images obtained through red, green, and blue filters on the Hubble Telescope's camera. The dark, fin-shaped feature is Syrtis Major Planitia, first identified in the 17th century. It is thought to be coarse sand, possibly deposited by the weathering of volcanic rock.**

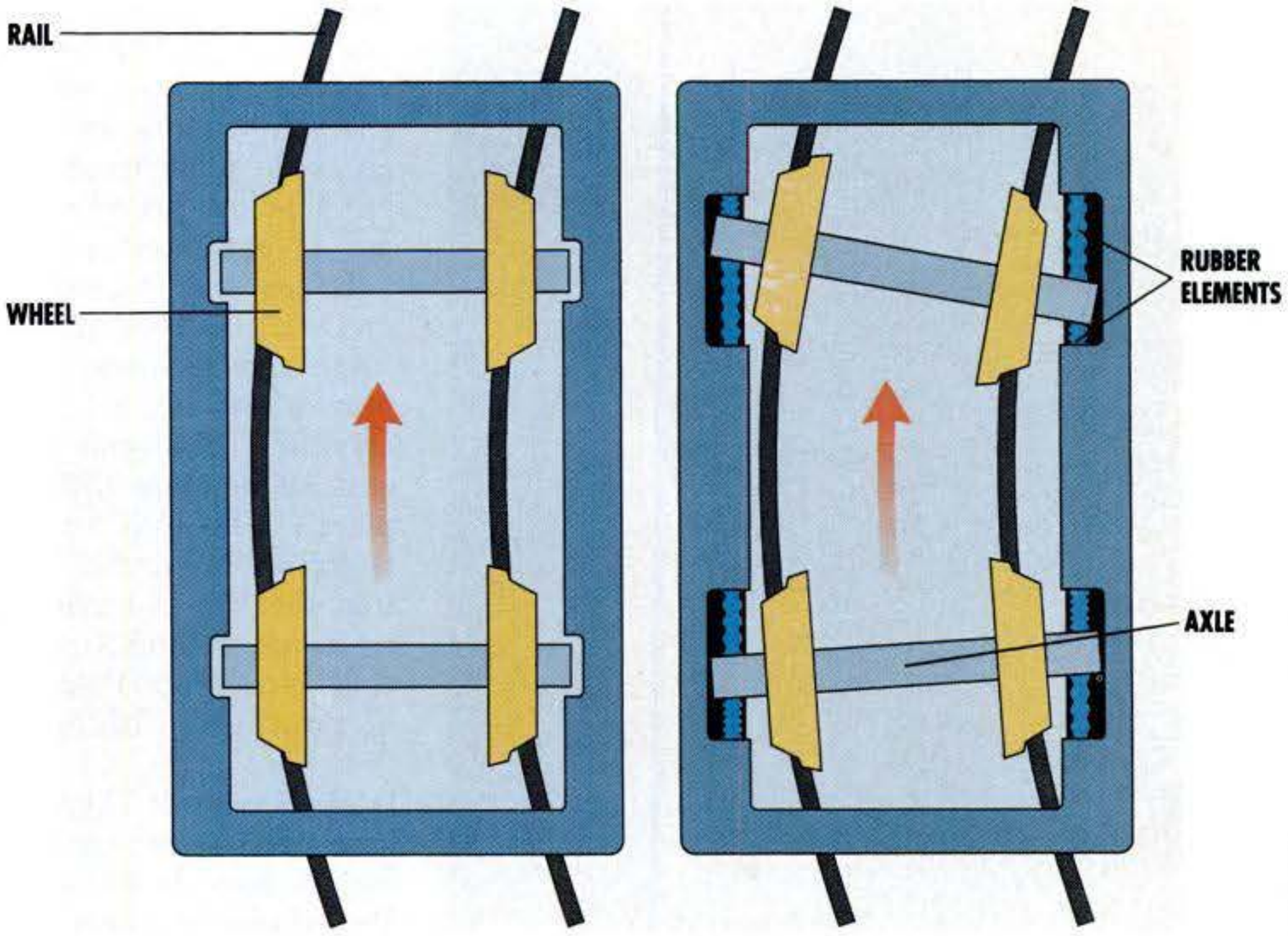
Scientists currently use a mathematical formula to reconstruct, or "deconvolve," the blurred images obtained by the telescope. The Mars image above, produced using the Space Telescope Science Institute's image-processing facilities, is the sharpest ever taken from Earth's vicinity. But the resolution is still only about half as good as it would be if Hubble's mirror had no flaw.

A team of planetary scientists recently began a long-term program to monitor weather patterns on Mars. Using Hubble's Wide Field & Planetary Camera, they hope to identify atmospheric cycles and surface conditions by comparing images obtained at different times during the Martian year. The Viking Landers sent back detailed pictures of the Martian surface in 1976, yet little is known about the planet's climate and seasonal changes.

## Swedish express

Rubber-mounted axles allow Sweden's new X2000 high-speed train to hurtle around tight curves on existing track. On the 285-mile run from Gothenburg to Stockholm, the train averages 96 mph despite a modest top speed of just 125 mph. Although the French TGV is far quicker on its special track connecting Paris to cities on the Atlantic coast, the Swedes calculate that on the winding Gothenburg-Stockholm run, the

**Sweden's X2000 train travels at high speeds on existing track because its wheels steer around bends; conventional axles move in only one direction. Rubber pads cushion the pivoting axles.**



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TGV could average no more than 87 mph, because it would have to slow down at curves.

Conventional train axles move only vertically, allowing wheels to go up and down over bumps in the rail. But in the bogies the Swedish-Swiss engineering company Asea Brown Boveri developed for the X2000, the axles are supported on all sides by rubber elements that allow fore-and-aft and slight lateral movements. The rubber cushions enable the train to go 40 percent faster through curves without any loss of safety, its designers say.

Hydraulic cylinders connecting the passenger compartments to their wheeled bogies allow the X2000 to lean into curves like a motorcycle. A pendulumlike device on the leading bogie of each car senses when it's entering a curve and feeds this information into the hydraulic system. Tilting doesn't make the train safer, but it does make passengers more comfortable.—*David Scott*

## Superconductor spirals

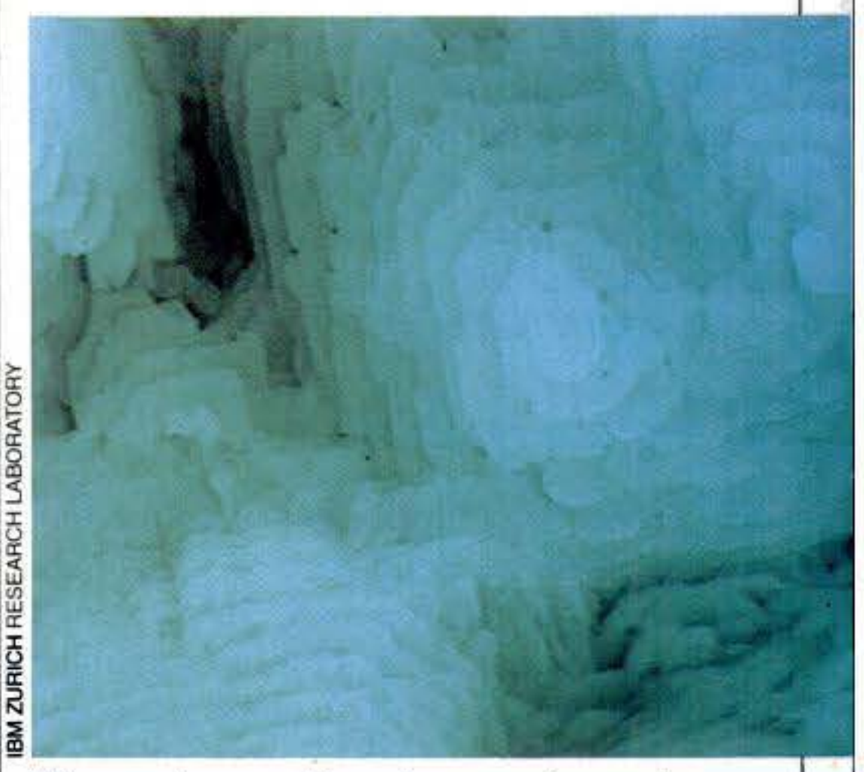
Two teams of scientists have discovered microscopic spiral structures in thin films of high-temperature superconducting material. The imperfections, called screw dislocations, may help explain why the films can carry large electrical currents.

Researchers at IBM's Zurich Research Laboratory in Switzerland and Los Alamos National Laboratory in New Mexico weren't aware of one another's work until both teams presented essentially the same findings at a meeting of the American Physical Society this spring.

"We've shown that these films are not composed of a single crystal but instead consist of many individual grains," says Ian Raistrick, deputy group leader for electronics research at Los Alamos. "Each grain grows by adding material to the edge of a spirally rising step. The steps grow outward as the structures grow up. This is by far the most graphic description yet of the real microstructure of the films."

Both teams studied films of yttrium-barium-copper oxide, a material that conducts electricity with virtually no resistance at the relatively high temperature of minus 320 degrees F—the boiling point of liquid nitrogen ["Superconductors Take Off," May]. J. Georg Bednorz, who led the IBM team, shared a Nobel prize for the 1986 discovery of high-temperature superconductivity.

Magnetic fields penetrate high-temperature superconductors as magnetic flux lines that move around, preventing the materials from carrying large currents. Both teams suggest the screwlike defects "pin" the flux lines in place, either directly at their cores or at the myriad boundaries between adjacent grains.



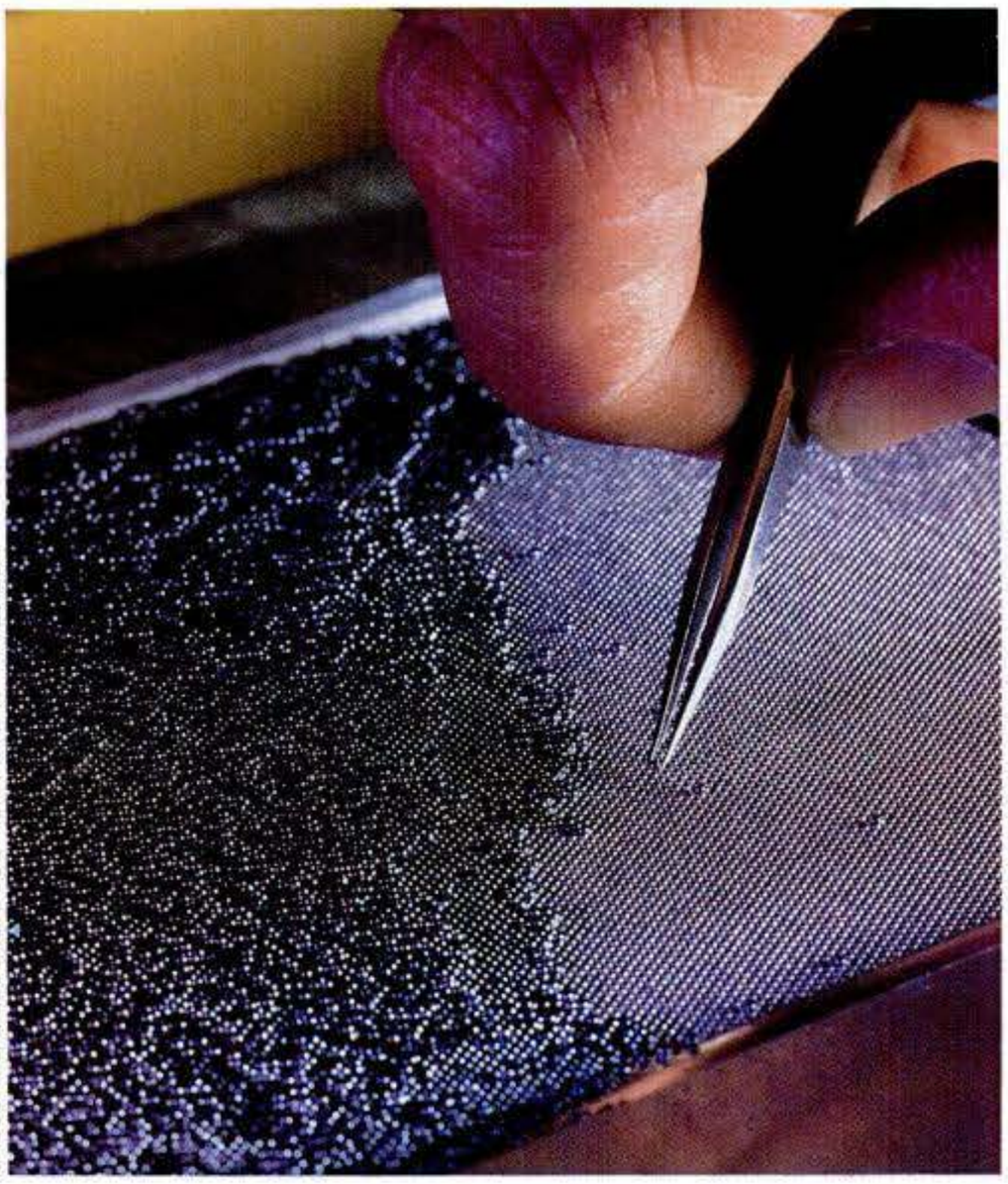
IBM ZURICH RESEARCH LABORATORY

**This scanning-tunneling-microscope image shows spiral ramps, called screw dislocations, in a thin film of high-temperature superconducting material.**

## Sun beads

Despite the promises of engineers, most devices that convert sunlight to electricity are low-watt novelties. But Texas Instruments and Southern California Edison Co. have developed a new breed of solar cell that could deliver clean energy at competitive prices.

Engineers at the two companies designed a tiny bead of silicon, phosphorus, and boron that kicks out a trickle of electrons when struck by photons from the sun. The Spheral Solar beads, which are bonded to sheets of aluminum foil, are easily made from low-grade silicon priced at $1 per pound. Most photovoltaics are expensive and tricky to assemble because they're made from purified silicon, a brittle crystalline material that costs as much as $35 per pound. "The stuff we use is full of impurities like iron that would be death to a conventional solar cell," says Nick Patapoff of Southern California Edison. When the silicon is melted to form beads, most of the impurities migrate to the surface and are removed.



GREGORY L. O'LOUGHLIN/SOUTHERN CALIFORNIA EDISON

**In Spheral Solar cells, 17,000 beads are pressed into four-by-four-inch sheets of aluminum foil. The conductive foil replaces wiring.**

After spending $10 million and earning 40 patents on the cells, the companies recently began test production in Dallas. Patapoff estimates that a 100-square-foot panel generating 1,000 watts might cost as little as $2,000. That would be one-fourth to one-sixth as much as a conventional photovoltaic cell producing the same amount of electricity. Patapoff believes energy-conscious residents with large roofs might even run their electrical meters backward by pumping unneeded power out of the house and into the utility grid on sunny afternoons.—*Mark D. Uehling*

## Tiny Velcro

Silicon sheets covered with millions of tiny mushroom-shaped grippers can be used as mechanical adhesives to join parts without glue or solder, researchers recently discovered. The sheets of "micromechanical Velcro" form strong bonds when pressed together.

Working at Carnegie Mellon University in Pittsburgh, assistant professor of electrical and computer engineering Michael L. Reed and two colleagues borrowed techniques used to make computer chips to create the silicon sheets. The sheets might eventually be used to bond computer parts to circuit boards, connect blood vessels during heart bypass operations, and anchor corneas during eye surgery.

"The initial thinking was to develop something that would be useful for joining blood vessels. It turned out that this appeared to have some application in the electronics area," says Reed.

"After thinking about it some more, it seemed that if we wanted to do biomedical applications it would make a lot more sense to have the stuff go di-



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rectly into tissue, rather than have it mate with itself," Reed recalls. This idea led to a second type of micromechanical Velcro—with barbed caps that can pierce and hold onto living tissue like a fishhook.

The barbed caps are about half the size of red blood cells and are four times smaller than the rounded caps. To make either type, the researchers first coat a silicon surface with a thin layer of silicon dioxide. Then they use chemicals to etch away selectively portions of the top layer, creating an array of silicon dioxide caps on silicon stems.

Unlike some conventional adhesives, the micromechanical Velcro can resist extremes of temperature, humidity, and chemical corrosion. Reed thinks they are safe for medical applications: "Silicon and silicon dioxide tend to be stable materials." He is discussing commercial development of the technology with a few companies.—*Oliver Fultz* PS

# MEET THE NEW TOP GUN

The angular, scrappy-looking YF-22, Lockheed Corp.'s candidate in the Air Force Advanced Tactical Fighter (ATF) competition ["Fast, Agile, Stealthy Supercruisers," Apr.] is now being referred to as the F-22 Lightning 2. It won. Vanquished Northrop Corp.'s sinuous YF-23 prototype appears likely to be headed for a museum exhibit of interesting airplanes that never made it into production.

How did the Air Force pick the recipient of what could well be the largest defense contract in U.S. history? Straight answers are hard to come by, but it appears that politics and business had at least as much to do with it as the technical merits of the competing fighter prototypes. By all accounts, both of the YF aircraft met Air Force performance requirements.

During an aggressive flight-demonstration program that was conducted last winter at Edwards Air Force Base in the California desert, Lockheed's contender, with its thrust-vectoring exhaust nozzles, became known as the more agile of the two aircraft. The prototype launched a missile from its internal weapons bay (even though the Air Force didn't require this) and made a total of 74 flights.

In comparison, Northrop's YF-23 (nicknamed both the Black Widow and the Gray Ghost) flew 50 times. Experts believed that its carefully contoured shape offered superior radar-evading stealth capabilities, while its exhaust-nozzle design almost certainly provided better suppression of the twin engines' infrared heat signature. The YF-23 also showed that it could be turned around quickly enough to be able to fly up to six missions in one day—an ability proven to be valuable during Operation Desert Storm. Although the Lockheed prototype reached a higher top speed with afterburners lit, Northrop's airplane was able to supercruise (efficiently fly supersonically without fuel-thirsty afterburners) at a higher speed—an attribute that is potentially more useful in combat.

In announcing his selection of the Lockheed F-22, Air Force Secretary Donald Rice said that the plane's price tag was lower than that of Northrop's YF-23, but he declined to cite any figures. Faced with a choice between two aircraft that testing had shown to be credible successors to the F-15 as the premier air-superiority fighter, the Air Force seems also to have paid heed to considerations beyond cost. This is probably what knocked Northrop out of the game. The focus of a spate of scorching congressional hearings and Pentagon audits over the past several years, the company has been charged with a range of improprieties, including faking test data on a guidance system for nuclear weapons. It has powerful enemies in Congress.

Lockheed, too, has had its share of foul-ups over the years. The company's giant C-5 military transports needed expensive new wings far too early in their service lives. Most recently, the Navy canceled the P-7 maritime patrol plane after Lockheed failed to keep the program on track. On balance, though, the company's image is cleaner than Northrop's, and the superb Desert Storm performance of its F-117 stealth attack plane certainly didn't hurt.

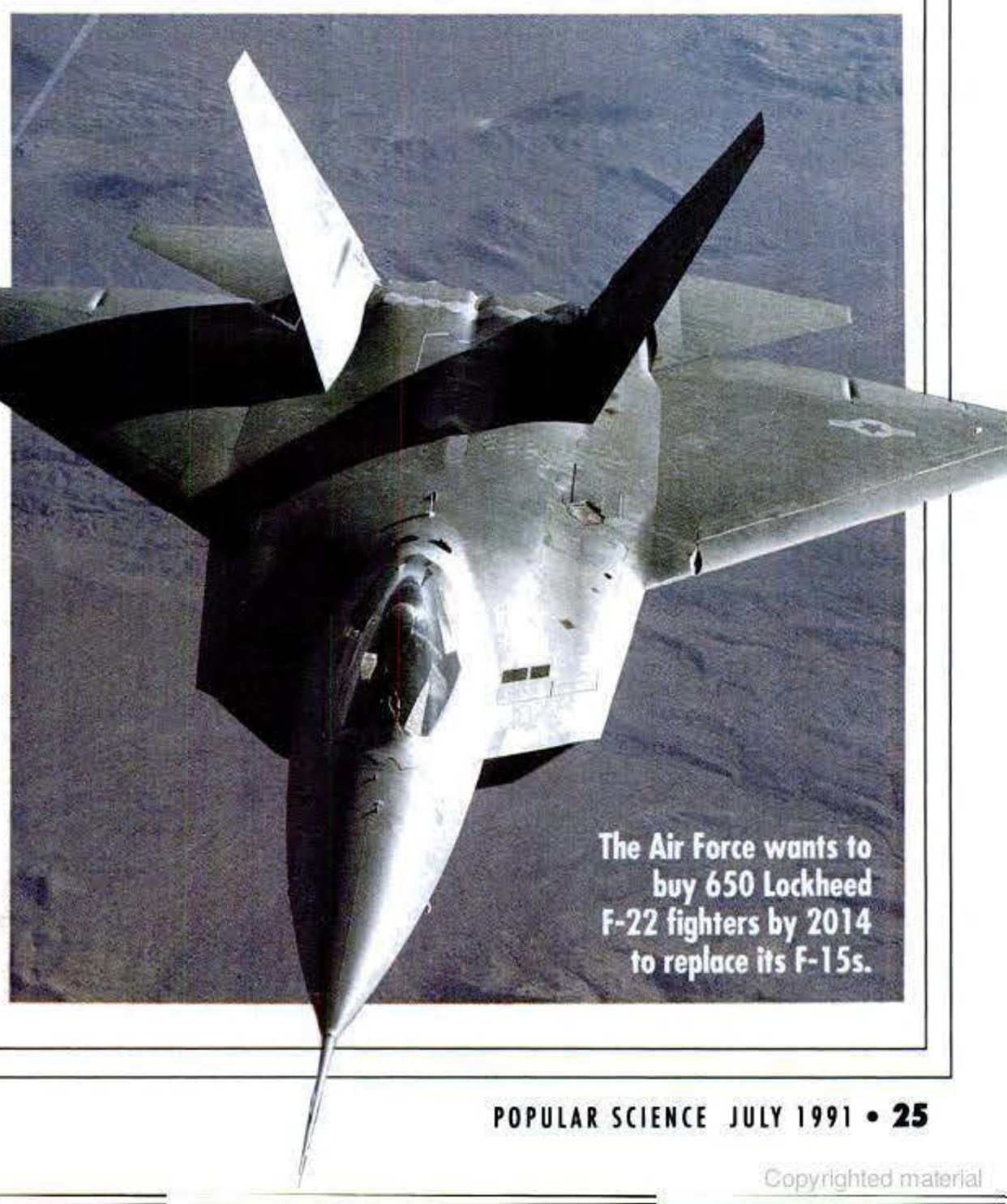
Financial stability in a shrinking defense industry is another element in what appears to be the current formula for winning a big Air Force contract. Along with its prosperous partners, Boeing Co. and General Dynamics, Lockheed seems to be unlikely to suffer logistical problems related to a lack of cash. Financial analysts judge Northrop and its partner, McDonnell Douglas, to be in a weaker position, dollarwise.

What else mattered? Lockheed showed political savvy in saying it would build the F-22 at its huge, underutilized plant in Marietta, Georgia, the home state of Sen. Sam Nunn, chairman of the Senate Armed Services Committee. In a statement, Nunn praised the Air Force for "a model acquisition program," adding that the award was "very good news for Georgia."

The Air Force gave the ATF engine contract to Pratt & Whitney, although rival General Electric's engine incorporated a variable-bypass feature said to reduce fuel consumption. Additionally, it was reported to develop more thrust than Pratt & Whitney's less complex design. A major point in Pratt & Whitney's favor was the trouble-free performance of its YF-119 prototype engine. A GE YF-120 engine in the Lockheed YF-22 shut down during flight testing, giving pilot Dave Ferguson plenty to think about until he concluded that his other engine would be able to bring him to a safe landing.

The ATF program could involve tons of money—from $60 billion to perhaps $100 billion if the Air Force gets the 650 fighters that it would like to buy over the next few decades. The Navy may further magnify the deal by ordering its own carrier-based version of the fighter. For now, however, the sums proposed are much smaller. The Air Force is trying to get congressional approval to launch a $14 billion engineering and manufacturing-development phase of the program this summer, which would yield 11 F-22s over the next eight years, with full-scale production to follow.

Still, it's quite possible that the ATF program could eventually lose its momentum. Many members of Congress remain unconvinced that the United States needs to spend huge sums to develop an entirely new generation of fighters, given the declining fortunes of the Soviet Union and the strong performance of the current-generation aircraft used in the Middle East. Don't rule out the possibility that the Air Force will be told to make do with derivative versions of the F-15 and F-16.—*Stuart F. Brown*



The Air Force wants to buy 650 Lockheed F-22 fighters by 2014 to replace its F-15s.



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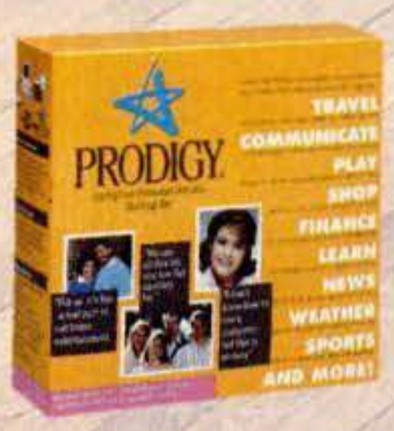


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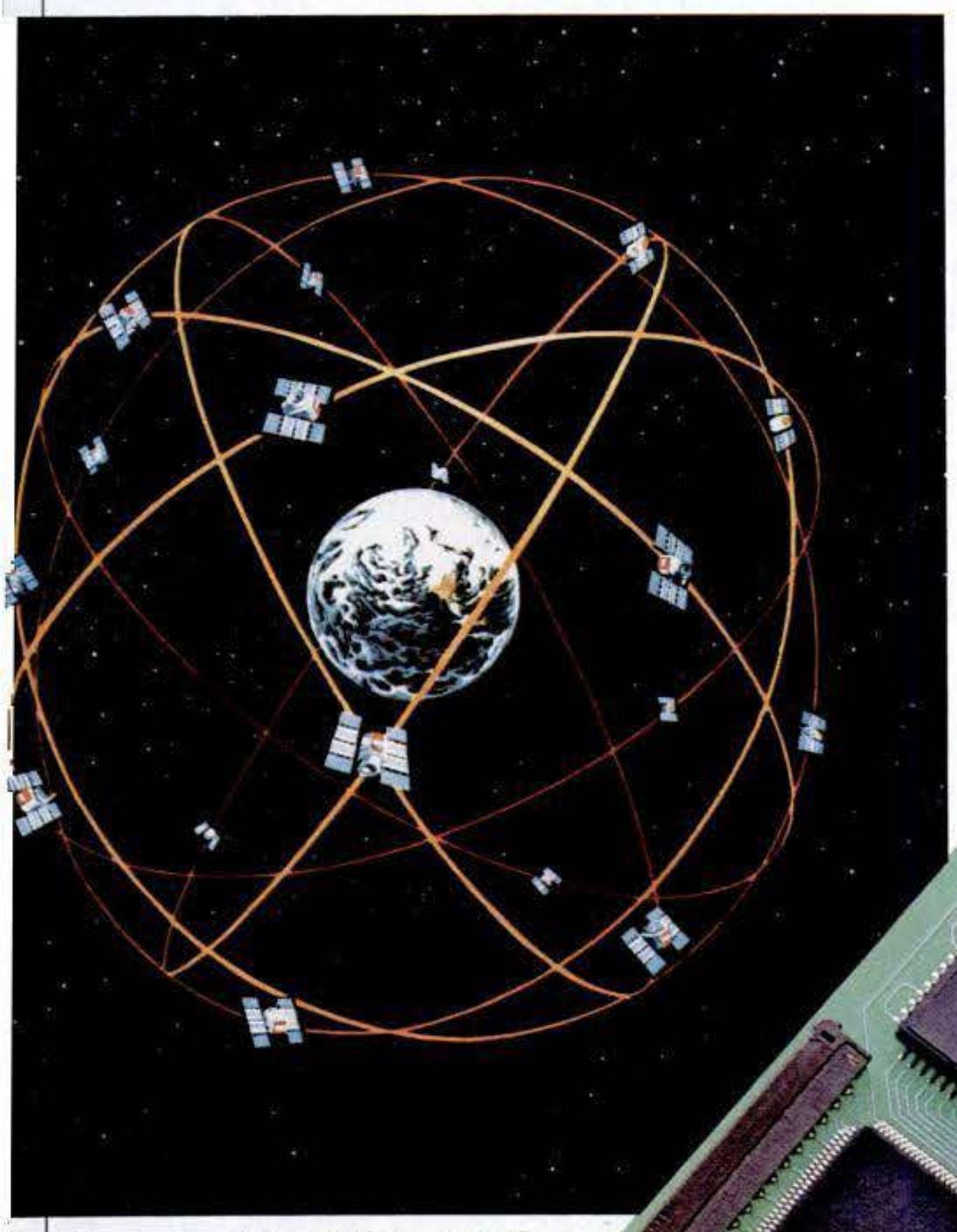
# Electronics Newsfront

**Edited by JOHN FREE**

## Budget satellite navigation

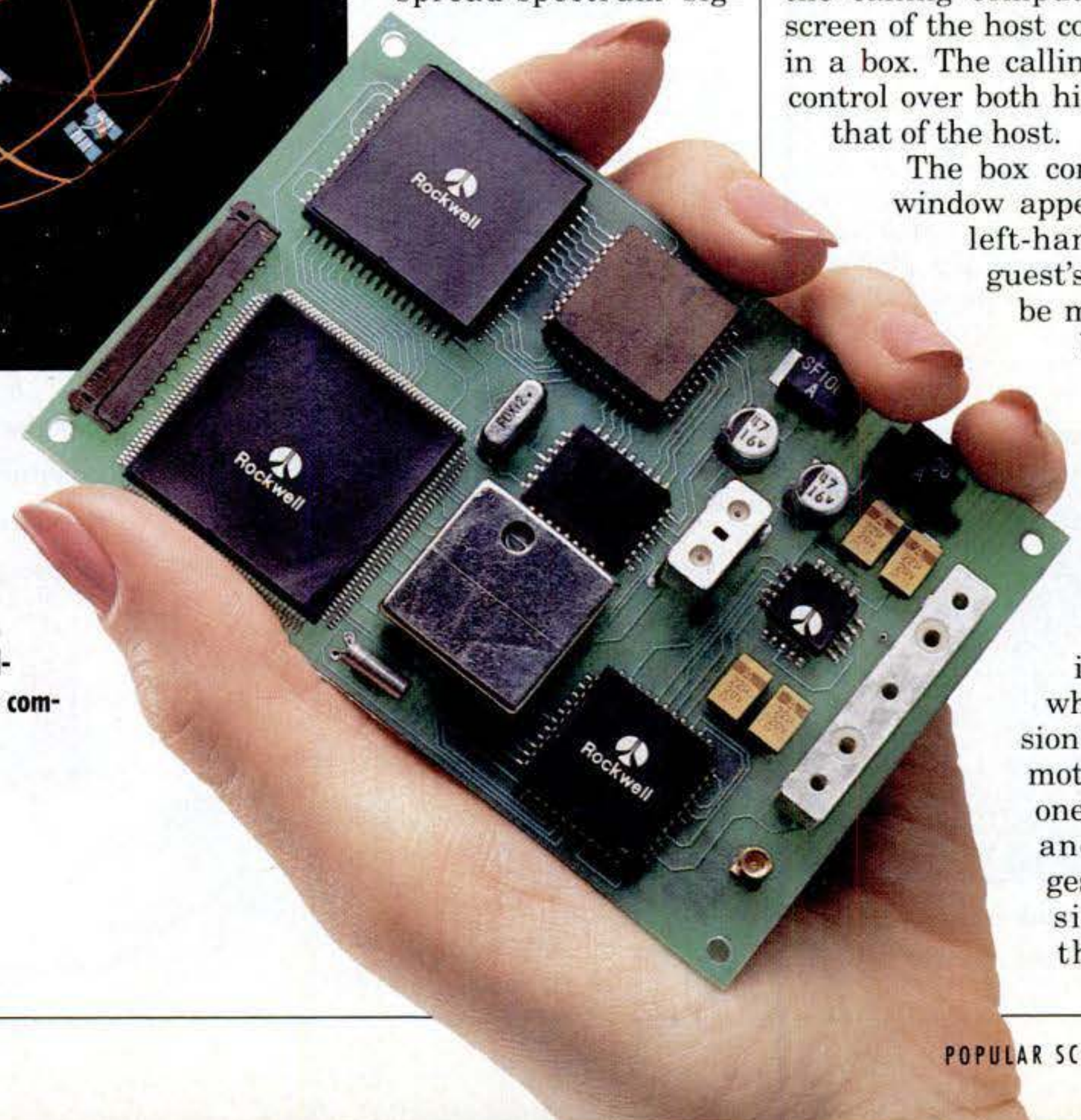
Shirt-pocket-size electronic modules tuned to signals from Navstar Global Positioning System (GPS) satellites will help guide boats, trains, cars, and other vehicles to their destinations starting next year. The compact modules, introduced by Rockwell Communication Systems in Dallas could also turn up in backpacks to aid hikers. Rockwell, which has made military GPS hardware since the early 1980s, shrank most of the circuits needed onto eight microchips.

GPS receivers, which read signals from four satellites to pinpoint the user's location, have been available for years. The military ordered some 10,000 units for the Persian Gulf war ["The Technology of Desert Storm," June]. Commercial models now cost from $2,500 to $5,000, according to Rockwell, which projects $1,000 to $1,500 price tags for receivers from manufacturers using its new module. The low module cost, initially $450 in small quantities, should help spread GPS applications into pleasure boats and cars.



Rockwell says the five parallel channels in its NavCore V receiver engine give it an advantage over models with fewer channels. "Having five channels on the engine means that an accurate reading can be taken in about thirty seconds, compared with nearly two minutes for a typical two-channel receiver," explains Roger Stevens, director of the company's commercial GPS program. Navstar satellites beam coded spread-spectrum signals, which are less prone to interference ["World Without Wires," Apr. '90]. The NavCore's fifth channel constantly scans the signals from space, selecting the best one available to override the weakest signal.

The NavCore's radio-frequency circuits use a one-eighth-inch-square gallium-arsenide chip with 1,291 components; a digital-signal-processing chip has almost 250,000 transistors. The module's low number of electronic components, says Stevens, is "most important from a cost, reliability, and quality standpoint."




**Four custom integrated circuits and four memory devices on Rockwell's 2.5-by-4-inch NavCore V receiver module help track all GPS satellites in view, using the four best signals to calculate locations to within approximately 300 feet. The military's complete Navstar system—21 satellites and three spares—is slated for completion in 1993.**

## On-line split screen

Farallon now offers Timbuktu/Remote 2.0 software, which allows a Macintosh user to connect to another remote Mac via modem or ISDN (integrated service digital network) links. Nothing new, right? Wrong: With the updated Timbuktu/Remote software, the screens of both the "host" and the "guest" computers appear on the user's screen simultaneously. I saw a demonstration in which Farallon set up two computers with modems. One Mac was ordered to pull the number of the other computer out of its telephone directory and dial. When the connection was made, the screen of the calling computer changed—the screen of the host computer appeared in a box. The calling guest now had control over both his own screen and that of the host.

The box containing the host window appears in the upper left-hand corner of the guest's screen and can be moved and resized by the guest. Any changes the host makes on his own screen show up immediately in the box on the guest's screen, even if the guest is working elsewhere. The old version of Timbuktu/Remote could show only one screen at a time, and Farallon suggests its revised version could make things easier for



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# BUG EYES PROMISE BRILLIANT SENSORS

By P. J. SKERRETT

In the tangled underbrush of the forest floor, ogre-faced Dinopsis spiders prowl at night, looking for food. They maneuver with ease in the pitch dark, find their prey hiding in the cluttered landscape, and pounce unerringly. Each of their prominent, headlight-like eyes comprises hundreds of microlenses with a detector behind each. Such eyes are superbly adapted for picking up patterns amid high clutter, detecting motion, and working with the least bit of light—functions that have stymied sensor designers for years.

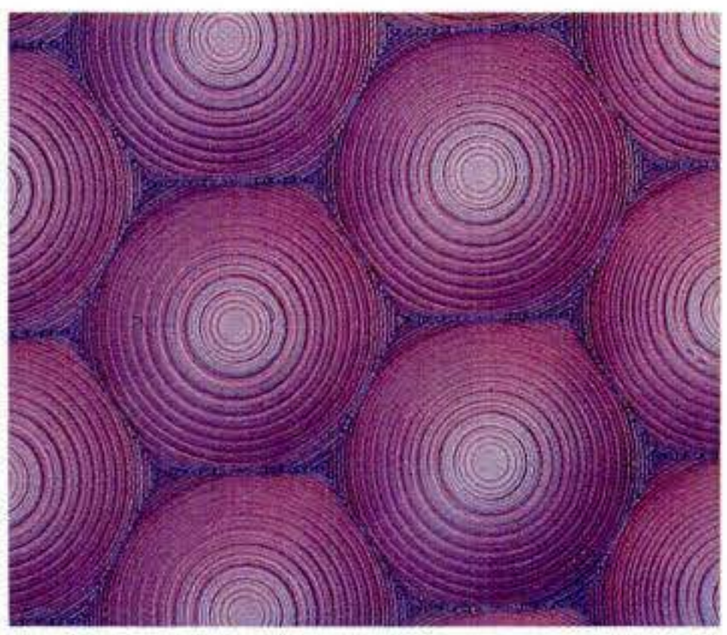
New research that marries optics and electronics may soon lead to smart sensors that mimic the spider—and the human—eye. Dubbed amacronic sensors, they could turn the "smart" weapons used in the Persian Gulf war into "brilliant" ones. On the home front, they could be used in cameras, navigation aids, even 3-D virtual-reality systems for entertainment and business.

"I'm convinced we are on the threshold of a whole new sensor technology," says Wilfrid Veldkamp, a group leader at Massachusetts Institute of Technology's Lincoln Laboratory. "Mother Nature is very good at specializing, and what we need to do is follow some of her leads."

That's why Veldkamp is developing amacronic sensors, modeled after cells in the amacrine layer of the retina, the light-absorbing layer at the back of the eye. These cells process visual data coming from the retina and substantially reduce the flow of information to the brain.

When scanning a wind-swept rolling meadow, for example, color, motion, shape, shadow, depth, the edge between one blade of grass and its neighbor all are converted into a flood of electrical signals, followed instantly by new waves of information. In human eyes, amacrine cells trap relatively unimportant information and pass along what is immediately useful. When you stand in a crowd, you only become aware of people in your peripheral vision when they move, even though your eye registers their presence while they are standing still.

But artificial sensors treat all input as equally important and can't handle the data. "You need something like a Cray supercomputer to handle this or else choke on all the information," says Veldkamp. Amacronic sensors could reduce the torrent of visual information using a new breed of lenses and parallel processors, allowing for smaller, faster, more responsive sensors. For starters, researchers at Lincoln Laboratory are concentrating on devices that would detect motion, recognize patterns, and selectively dim parts of the image that are too bright, a process called dynamic range reduction. Here's how the devices would work:



Microlenses with hair-width diameters would coat amacronic-sensor signal processors.

At the front end, binary optics replace conventional optics. These lenses, with diffraction patterns etched on their surfaces, are made using photolithography and masking techniques adapted from microchip production. They can be as small as a few microns in diameter, and thousands can be packed onto a wafer (see photo).

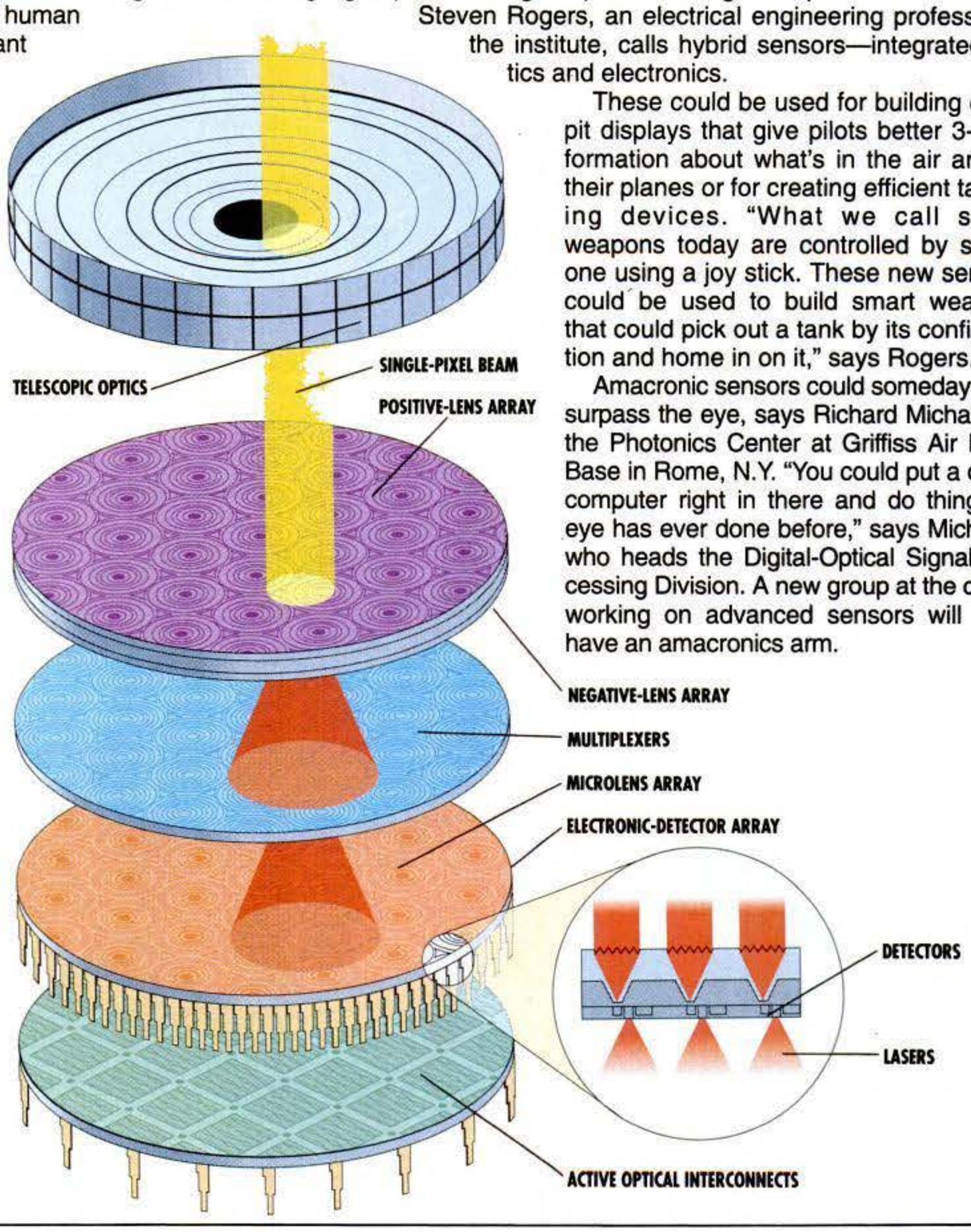
Low-power analog-signal processors, linked picture element for picture element behind each microlens, analyze the incoming visual information. Working in parallel, the processors form limited networks of circuits akin to nerve cells or neurons. Output from one layer of processors analyzing and modifying incoming light intensity, for example, could be passed to another layer working on motion detection via diode lasers (see diagram). The highly processed output from this "sensor sandwich" would streamline the data flow and only pass along desired information.

The components for such a system are "right at the edge of technology today," says Veldkamp, holding up a wafer with thousands of binary-optic lenses etched on it. Integrating such lenses into sensor systems will take another year or two.

Smart sensors could have a variety of applications. Veldkamp describes a camera that detects motion, turns, points, and focuses by itself, or a telescope that locates a section of the universe by homing in on specific star patterns. The first working amacronics devices will likely be developed by the military. At the Air Force Institute of Technology at Wright-Patterson Air Force Base in Ohio, a large group is working on pattern recognition problems with what Steven Rogers, an electrical engineering professor at the institute, calls hybrid sensors—integrated optics and electronics.

These could be used for building cockpit displays that give pilots better 3-D information about what's in the air around their planes or for creating efficient targeting devices. "What we call smart weapons today are controlled by someone using a joy stick. These new sensors could be used to build smart weapons that could pick out a tank by its configuration and home in on it," says Rogers.

Amacronic sensors could someday even surpass the eye, says Richard Michalak of the Photonics Center at Griffiss Air Force Base in Rome, N.Y. "You could put a digital computer right in there and do things no eye has ever done before," says Michalak, who heads the Digital-Optical Signal Processing Division. A new group at the center working on advanced sensors will likely have an amacronics arm. PS

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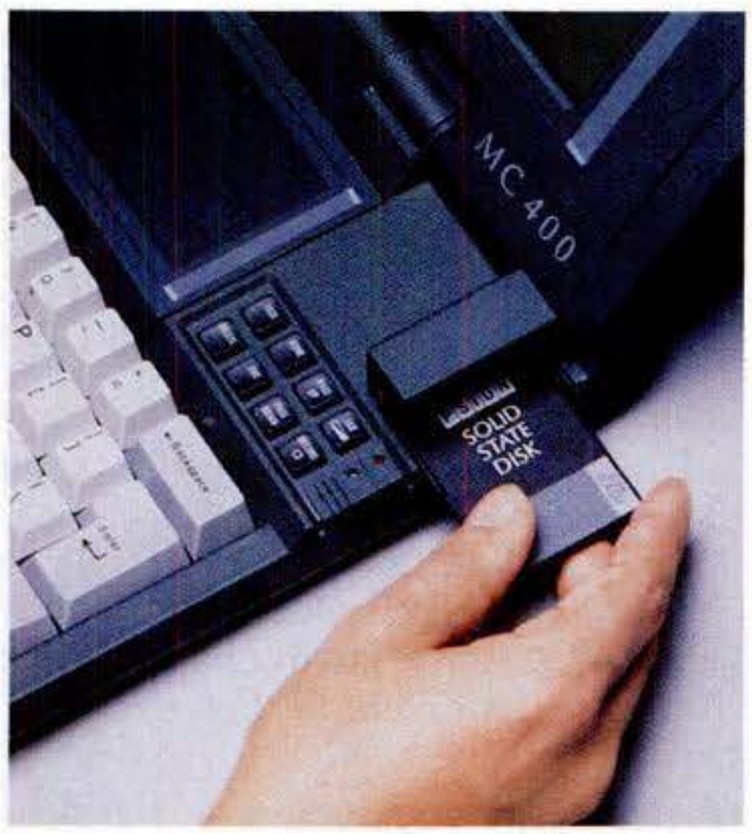



**Solid-state modules used in place of floppy-disk drives in Psion computers now have greater memory capacity. Modules store data permanently.**

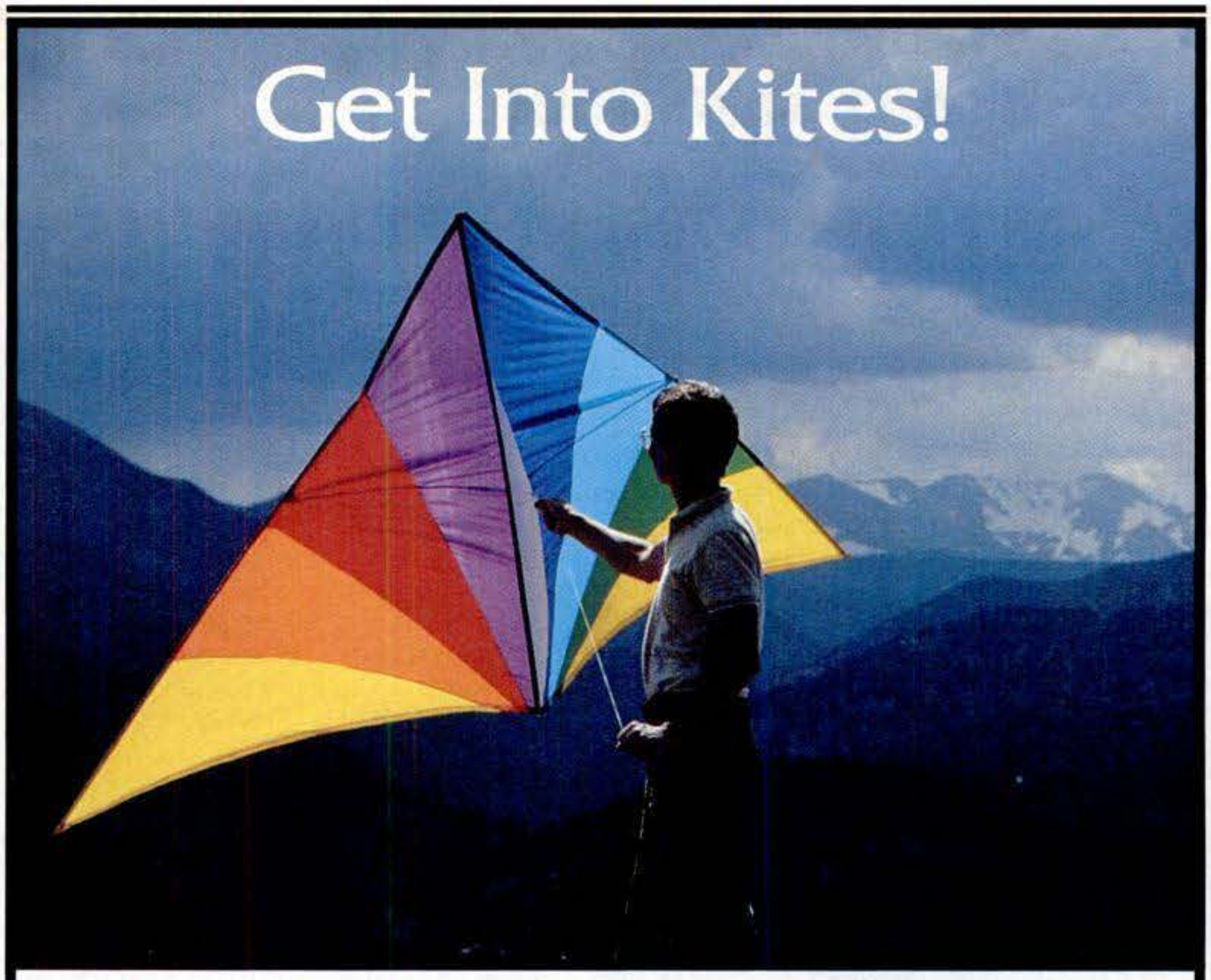
users in remote locations who are collaborating on a project or spreadsheet. Suggested retail price for the software: $195 from Farallon (2000 Powell St., Emeryville, Calif. 94608). —*David Peterkofsky*

## Floppy on a chip

Solid-state disks—memory chips that are used in place of magnetic computer disks—offer big advantages in terms of speed and reduced power demand. Because the plug-in, matchbook-size memory modules don't require a mechanical drive, they also offer huge space savings. Their disadvantage is lack of compatibility with the diskettes used by most computer owners.

Psion, the British company that pioneered solid-state disk substitutes, recently expanded the memory capacity of its modules, from 512 kilobytes to 1 megabyte; a two-megabyte module will soon be available. The modules use Intel "flash" chips that retain stored data without power. The chips can also be erased electrically within the computer.

Psion's memory modules have the data-file-handling characteristics of the much slower mechanical disk drives they replace, so you can use familiar commands. Because the modules don't need a special power supply, Psion's all-chip computer has a battery life up to 20 times longer than most disk-based portables. The company's Mobile model is 12.4 by 8.9 by 1.9 inches and weighs 4.3 pounds. Four modules can be plugged in at once, so a large selection of software and data can be carried. Psion Inc., the U.S. distributor, is located in Watertown, Conn.—*David Scott*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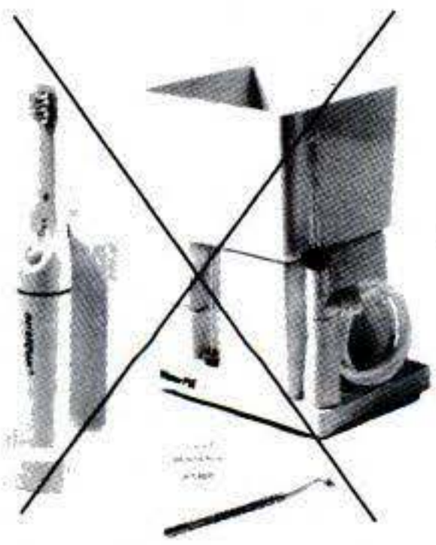

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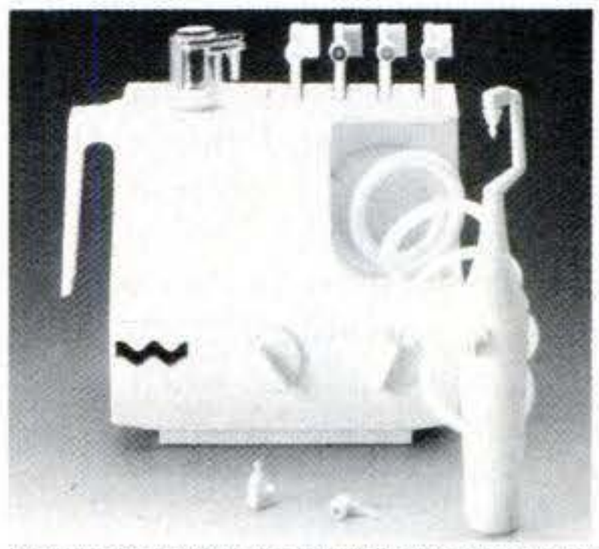

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## WORK STATIONS THAT FIT IN YOUR BRIEFCASE

Serious number crunching for complex statistics or engineering problems often involves powerful computer work stations anchored to desk tops. This fall, Zenith Data Systems in Buffalo Grove, Ill., will start selling its SupersPort 486, a lap-top that delivers work-station performance. At an unveiling this spring, Zenith claimed its new computers (a less-expensive 486SX model will also be offered) are the first lap-top PCs to use Intel Corp.'s high-end 486 and 486SX microprocessors. The 25-megahertz 486 chip, capable of some 11 million instructions a second, includes circuits for floating point calculations. The SX version lacks these number-crunching circuits, which can be added to most PCs with a plug-in math co-processor.

Backing up this processing power in the new lap-tops is a 120-megabyte hard drive, a 1.4-megabyte microfloppy drive, and four megabytes of memory (expandable to 16 megabytes). The 15-pound lap-top, housed in a magnesium cabinet, measures 12.1 by 15.1 by 3.1 inches. Its black-and-white 10.7-inch liquid-crystal screen can display 64 shades of gray. A battery charge lasts three hours. An optional docking unit for desk-top use accepts high-resolution video cards or other hardware. The 486 model will cost about $10,000; the SX version, about $8,000.

Mouse manipulators will need retraining for the Isopoint cursor-movement device below the space bar. Tap the left or right sides of the Isopoint bar with your thumbs to shift the cursor horizontally. Spin the bar for vertical cursor movement.—*J. F.*

**A detachable keyboard on the SupersPort 486 can aid typing comfort. The high-capacity hard drive has Windows 3.0 already installed.**

### Signal processing for ears

If Dr. Janet Rutledge has her way, individualized hearing aids with computer software will one day be as common as prescription eyeglasses.

Rutledge and her colleagues at Northwestern University's Robert R. McCormick School of Engineering and Applied Science in Evanston, Ill., envision a portable hearing-aid system that contains software designed for each patient's range of hearing.

Rutledge's system is based on digital processing—a technology that's used in cellular phones and compact-disc recordings. The system does not simply amplify sounds, as current analog hearing aids do, but digitally reconstructs and modifies sound.

For people with a conductive hearing loss—a condition that causes uniform reduction in hearing, like having a plug in the ear—making the sound louder works. But for those with a sensori-neural hearing loss caused by damage to the inner or outer ear, amplifying sound doesn't work. Such people have a narrow range of hearing because their threshold for hearing is higher than a normal person's, but the point where sound becomes painful is the same.

Rutledge's program is aimed at helping people with a sensori-neural hearing loss. The program runs on a personal computer attached to a digital sound processor. The processor converts speech into numbers that the computer manipulates. An algorithm, which Rutledge patented, is used to modify speech by considering variables such as voice range and the level of background noise. "In analog systems, the processing stays fixed, based on the average. But this system adjusts according to time and frequency," she explains.

To reconstruct speech, the program breaks the sound into sinusoids. "A sinusoid is a pure tone," explains Rutledge. "Each key on a piano could represent a sinusoid. When you play the different keys, you develop certain sounds." Stringing sinusoids together simulates sounds.

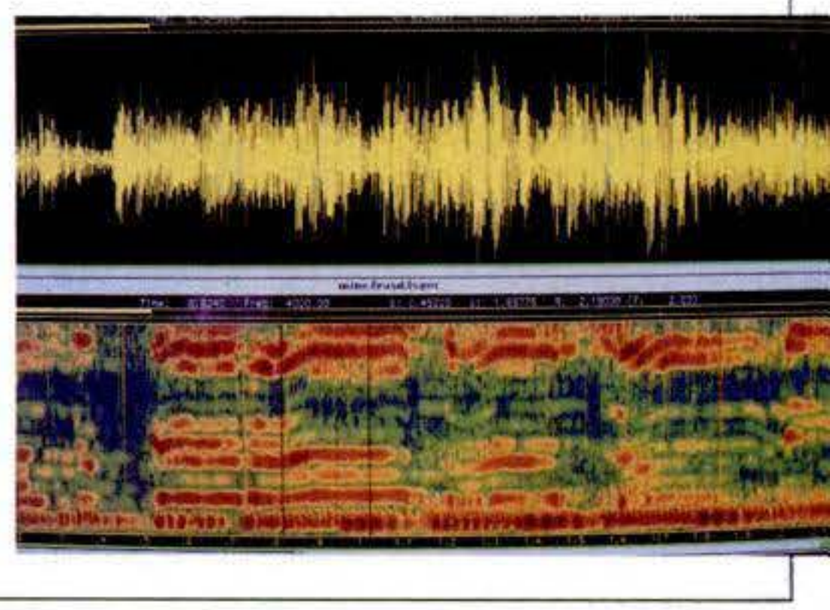
But digital signal processing takes considerable computer power. Rutledge's system might fit a walkman-size package five years from now. The present goal is a prototype about the size of an answering machine that would cost less than $3,000 if someone marketed it. A unit small enough to fit within the ear may be a decade away.

The technology could also be used for ground to helicopter communications. "It's suitable anyplace where you need to make speech more intelligible in a noisy environment," says Rutledge.—*Marcelle M. Soviero*

### Animated software

Hand-drawn or computer-generated cartoon animations only approximate human movements. Now an animation software package has been developed that replicates exactly the way humans move from one position to another. Dr. Tom Calvert at Simon Fraser University's Graphics Research laboratory in Vancouver, B.C., directed the development of the original software to help with choreography. Cole Larson, president of Kinetic Effects in Seattle modified this program to create Life Forms, a general-purpose animation program. Says Larson, "Life Forms will be to the animator as word processing is to the writer."

The software includes libraries of animations, such as pedestrian or sports movements. To develop an animation from scratch, you first create key frames, a sequence of movements necessary for the final animation. You either manipulate each body part into



**A digital-signal-processing program reconstructs speech. Top, speech patterns for the word "Bob" are displayed. Below, yellow wave forms illustrate sound waves over time; orange waves indicate where amplitudes are loudest, the blue waves, lowest.**



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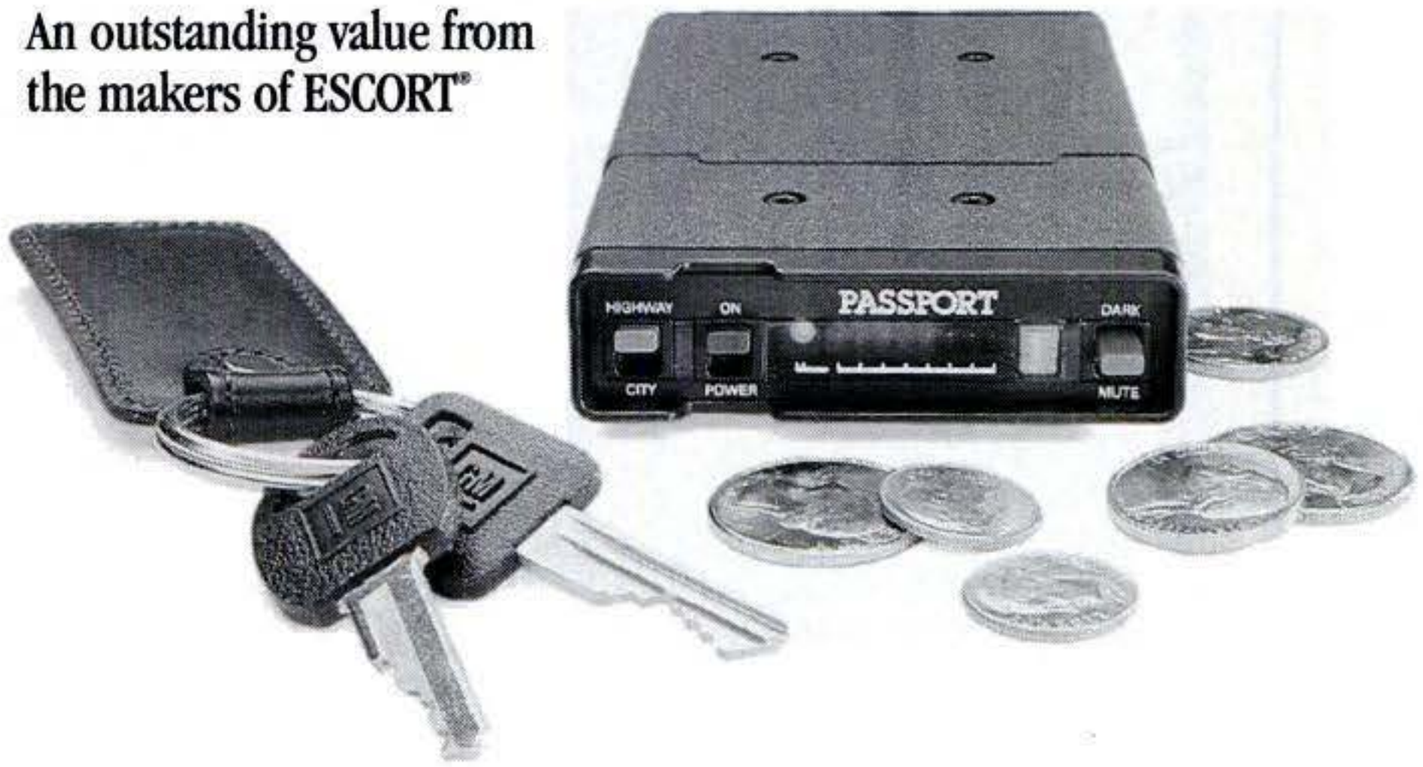


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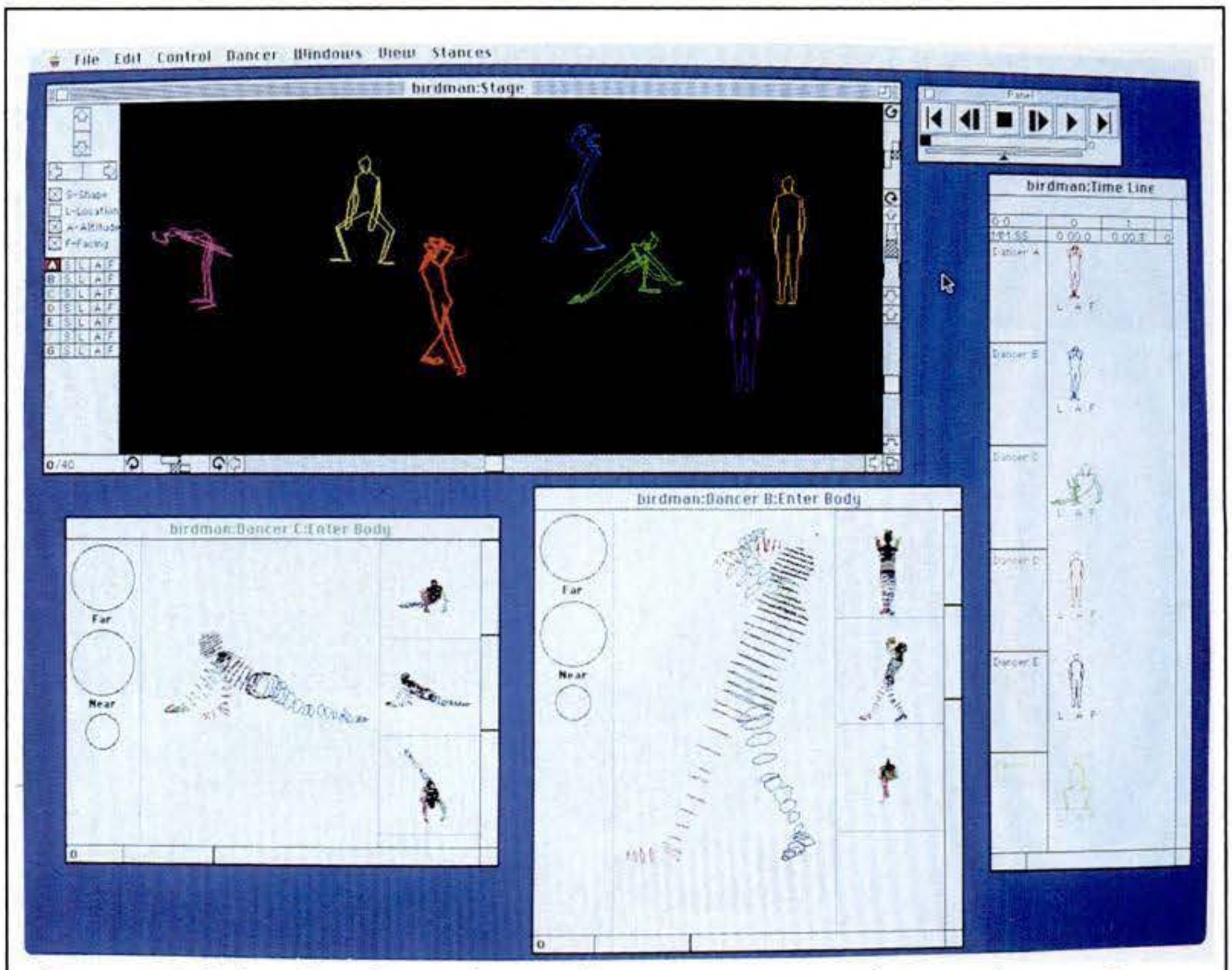



**Changes in the body and time-line windows in Life Forms, an animation software package, can be viewed immediately in their final form via the stage window.**

the correct position or select from a bank of figure positions, called shape pallets. As each key frame in the movement sequence is composed, you place it on a time line on the screen. The time-line editor adjusts how long it takes to move from one frame to the next. The computer calculates the intervening positions in a process called tweening. Finally, you determine the direction of the movements and their orientation in space on the program's stage screen.

At this point you can see your character perform in a lifelike fashion, and several animated characters can interact on the screen. The animation can be exported to Apple's Hypercard, MacroMind's Director, or Paracomp's Film Maker or Swivel 3-D. To be available later this year for Apple Macintosh and Silicon Graphics Computer Systems, Life Forms helps create realistic figure animations suitable for a variety of multimedia applications, or it can be used to choreograph human movement and test human-interface designs.—*Suzanne Kantra*

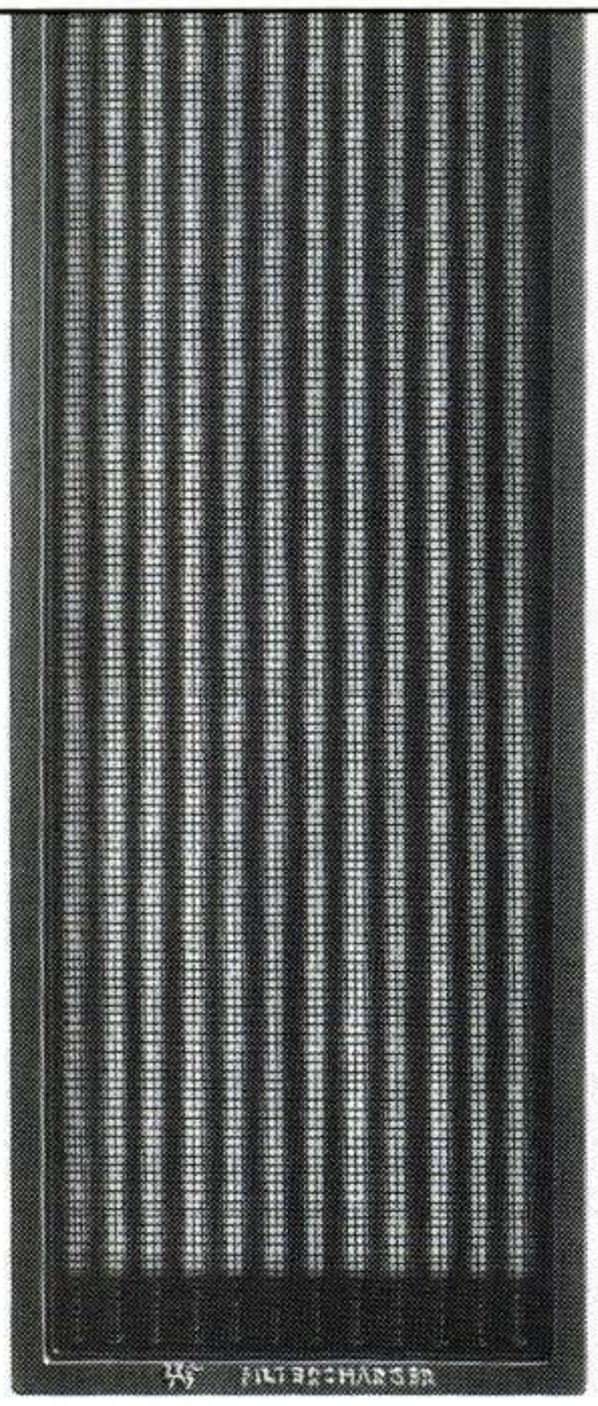
## Electronics notes

•New types of chips called monolithic microwave integrated circuits (MMICs) promise collision-avoidance radar systems for your car, ultracompact satellite antennas, and more. The National Institute of Standards and Technology is helping the electronics industry measure MMIC performance. The chips use precisely engineered pathways instead of wire to guide microwaves. Older bulky circuits require plumbinglike features, are more expensive than MMICs, and sometimes occupy as much space as a table top.

•Beware of shady characters offering plug-in chips for cable converter boxes so you can view premium movie channels for free. A Queens, N.Y., cable company fed a special signal along its lines that zapped several hundred converters, shutting off all channels. When angry customers complained, the company threatened to prosecute unless they started paying for their movies.

•Researchers at Duke and Cornell universities have created a specialized parallel computer than uses thousands of individual processors to analyze and draw 3-D objects. Called the RayCasting Engine, the computer promises to aid mechanical design, quickly creating mathematical models of complex geometric shapes. The Duke-Cornell team is adapting the unit for work stations and says a commercial model, priced below $100,000, could be available in several years.

•Glass-ceramic hard disks being developed by Corning Inc. will store twice as much computer data as standard aluminum disks, says the company. The heat-treated glass can be made approximately six times smoother than metal after it is coated with a magnetic material. PS

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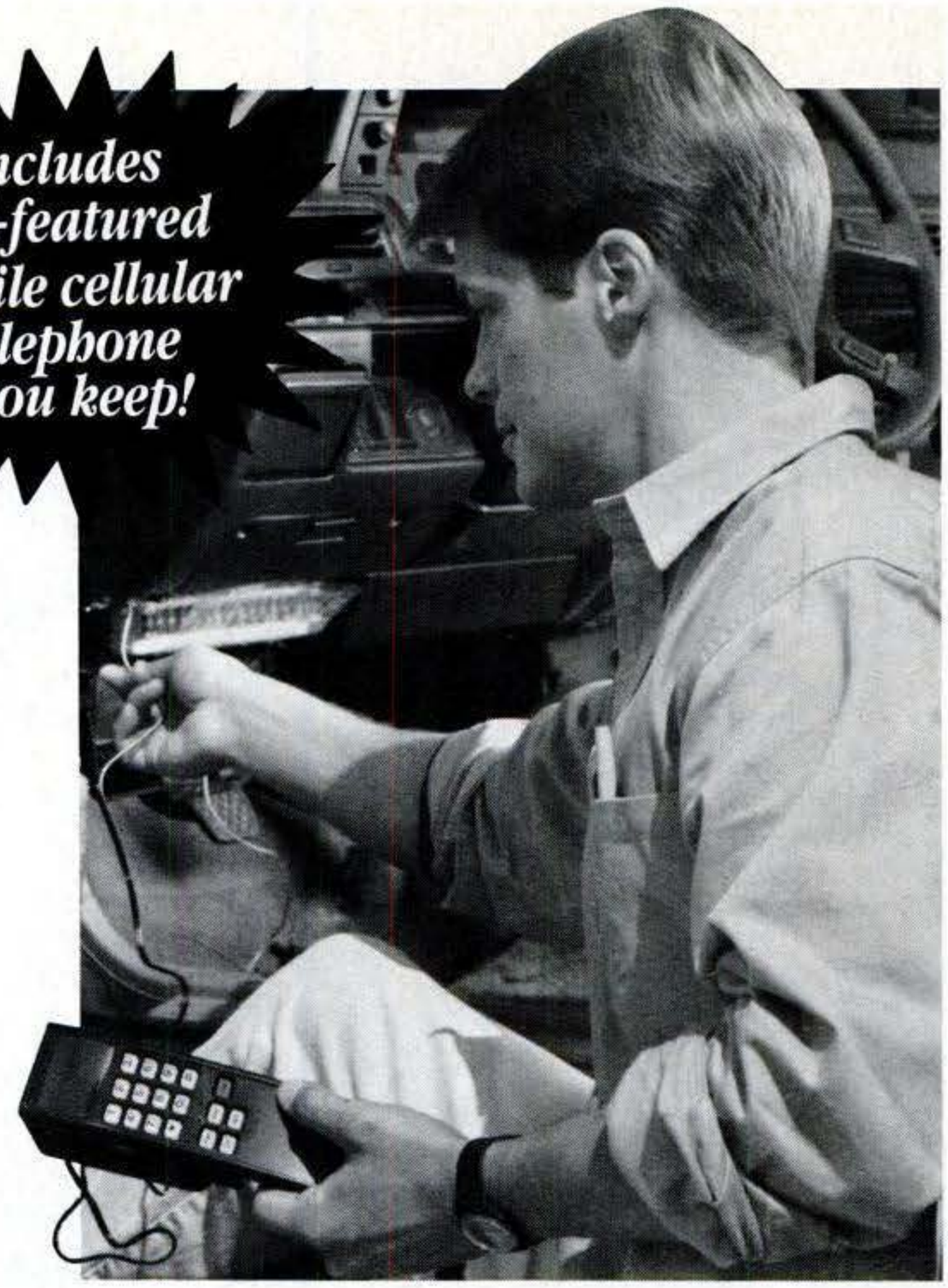


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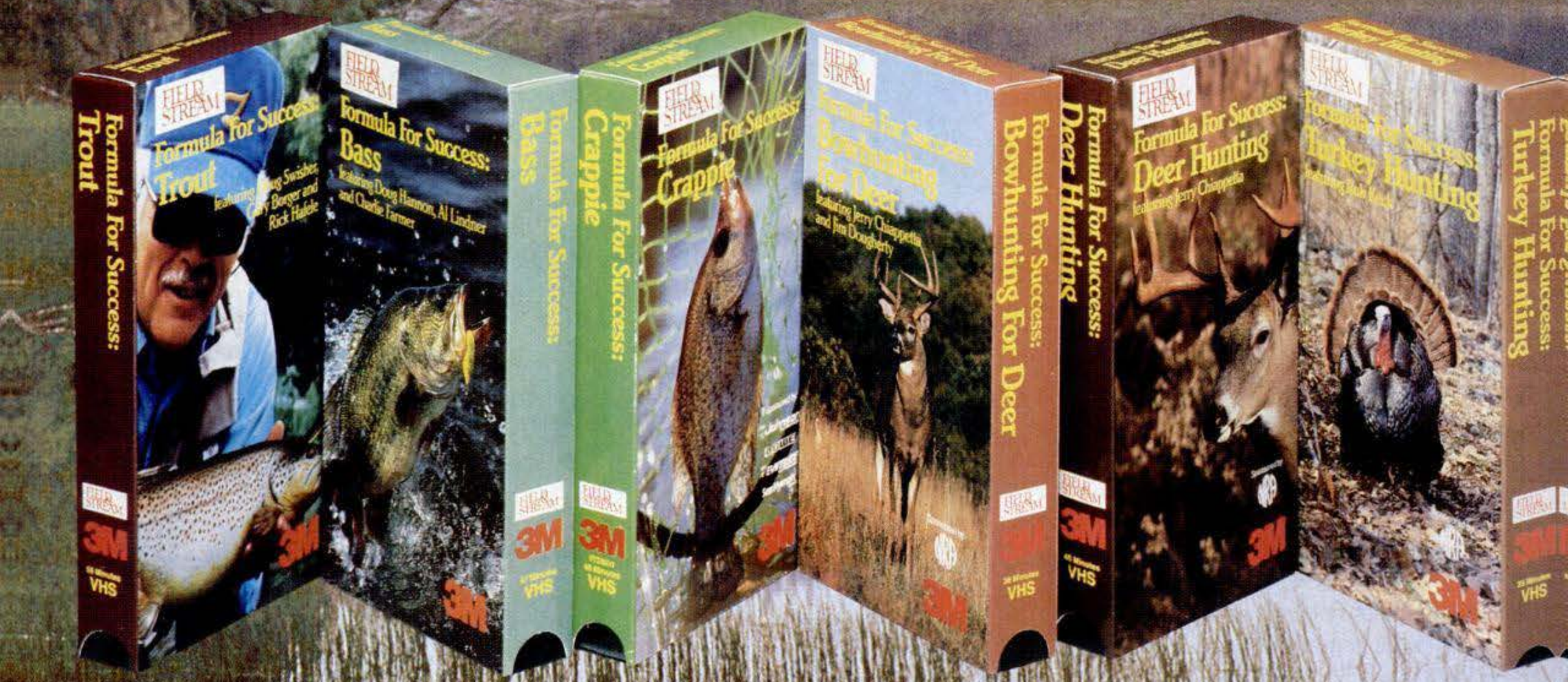
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# Automotive Newsfront

**Edited by DAN McCOSH**

## Germany plugs in

Although electric cars are getting a forceful boost from pending U.S. emissions laws, they don't seem to be getting the same attention in Europe. However, growing concern over the environment in Germany is renewing interest in the fumeless wonders.

One promotional effort followed these three easy steps: Get the country's leading public utility corporation to bankroll the project, wrap it in a snazzy body, and bill it as the fastest electric car on the market.

That's the story of a slick 70-mph 2+2 coupe developed and funded by the giant Rheinisch-Hastfalisches Elektrizitätswerk in the Ruhr heartland's Essen. The Pohlmann E1 boasts a clean-lined fiberglass body with a wind-slicing wedged nose unbroken by any cooling air intake. High-rise gull-wing doors hinged at the roof center line include flip-up air scoops for ventilation and need only a foot of side clearance to open, allowing close-in parking.

The main power source is lead-acid batteries, housed in water-ducted trays that keep them cool in summer and warm in winter to maintain peak efficiency. With regenerative braking, which taps electrical energy from the drive motors to decelerate, the car is said to have a 65-mile range at a constant 35 mph —still unsatisfactory for today's electric-car proponents, who are looking to a 150-mile range as a practical minimum.

One unusual electrical feature is the ability to switch the two drive motors between series and parallel. For maximum tractive power during start-up and at low speeds, the two motors are connected in series; then, at about 28 mph, they are switched over to run in parallel for cruising speeds. A throttle pedal kick-down flips the two nine-horsepower motors back to series wiring for a burst of acceleration, while speed is controlled by a thyristor chopper, a device that controls the speed of the direct-current motor.

The use of two drive motors, connected by tooth belts to the inboard ends of the axle half-shafts, creates a natural torque split between the drive wheels that replaces a lockable differential.

Overall, the Pohlmann E1 is an impressive effort, although it's questionable whether it deserves top-speed honors, because the German car has half as much power on tap as General Motors' all-electric Impact.

The tidy drive train of the Pohlmann E1 contrasts with that of an experimental BMW electric car incorporating an energy-storage flywheel, an energy-saving device often proposed for electric vehicles but rarely tested.

The BMW system was developed to help reduce the large current surges inherent in accelerating and decelerating an electric car. Reducing these surges promises several benefits, including an increase in the lifespan of lead-acid batteries. It also helps overcome the relatively low power density of the light-

**The steeply slanted nose of the Pohlmann E1 houses twin electric motors connected via cogged belts to separate drive shafts. The system eliminates the need for a universal joint.**



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weight, high energy-density sodium-sulfur batteries, which aren't particularly good at supplying heavy current for short periods.

In the test vehicle, the BMW flywheel is mechanically coupled to a planetary gearbox and the electric drive motor. A series of electrically operated brakes engages the spinning flywheel to accelerate the car. During deceleration, energy is stored by a gyro to help brake the car.

Although the system seems promising in theory, initial test results were disappointing. The main problem that confronted BMW engineers was the inability of the batteries to soak up all the current generated during the braking cycle.

BMW still believes that with further development, the setup will allow the use of a smaller, and therefore cheaper, sodium-sulfur battery pack for future electric cars.—*David Scott*

## Unmanned dumping

Small automated guided vehicles have been carrying mail and delivering parts around the world's offices and factories for several years. The same idea now is being applied to bigger things—namely, two 77-ton-capacity driverless dump trucks tooling around a rock quarry in Japan.

With a control system developed by Shin Caterpillar Mitsubishi and Nittetsu Mining Co., the two dump trucks are performing tests, shuttling between the working face of a limestone quarry and a hopper. At the quarry face, the trucks stop to let a human-operated wheel loader fill them with limestone. At the hopper, the trucks back into position and automatically dump the rocks for funneling onto fixed conveyors.

The trucks are fitted with computerized controllers that do the driving, following information from a dead-reckoning navigation system that uses a gyrocompass and speed sensors to track the truck's progress from a fixed starting point. The route is programmed by entering a series of x-y coordinates on a lap-top computer in the truck cab.

Engineers worried that the site's slippery surfaces and bumps would throw the tracking system off. To self-correct it, the trucks emit infrared signals that bounce back from several reflective posts spaced around the site. Sensors pick up the reflected signals, and the on-board computer refigures the truck's position.

In the future, the system may be used on construction sites, but it will need increased capabilities. For one thing, the controlling program isn't able to handle vertical coordinates yet, restricting use to relatively flat sites. —*Dennis Normile*

## Emissionless mission

Mazda Motor Corp. has joined the search for a car with zero emissions, and like Mercedes Benz and BMW, it is considering hydrogen. Mazda recently announced that it has been testing a developmental hydrogen vehicle and is planning to mass produce hydrogen-powered passenger cars and light commercial vehicles by the end of the decade. The most formidable problems, however, may not be developing the cars themselves.

Mazda will unveil its early prototype at this autumn's Tokyo International Motor Show. The car is based on its Capella station wagon, fitted with a modified 1,308-cc 13B rotary engine, which is used in Mazda sports cars. The auto maker claims this modified engine develops 60 percent of the output of the same engine running on gasoline and can travel up to 124 miles on one tank of fuel. Storing that fuel is one of the key challenges facing hydrogen-car developers.

Mazda isn't revealing much yet about its fuel-storing technology, but it did say its tank uses titanium-based and other alloys that absorb gaseous hydrogen. The gas is released when the alloys are heated.

It sounds a lot like Mercedes' approach, in which powdered metal alloys form hydrides with gaseous hydrogen within the car's fuel tank. But a Mazda spokesman declined to discuss exactly what the two technologies might have in common.

Over the next four years, Mazda is planning to concentrate development in four areas—stabilizing the ignition,

PREVIEW DRIVE

## VOLKSWAGEN'S NEW GREEN DIESEL

Volkswagen is claiming to make the cleanest production diesel in the world with its new Jetta GL ECOdiesel. That's still not clean enough for future California emissions standards, but it goes a long way toward eliminating the diesel engine's most persistent form of obnoxious behavior—the smelly black particulates characteristic of most diesel exhaust.

Environmentally, diesels have several advantages over gasoline. They are inherently lean-burn engines, consuming profuse quantities of air to burn fuel, which tends to reduce the production of carbon dioxide, the primary gas contributing to global warming.

VW takes this lean-burn advantage a step further in the ECOdiesel, using a low-pressure turbocharger as an air pump to improve combustion efficiency. The low-boost turbocharger reduces the formation of carbon particulates—the highly visible diesel soot.

VW then adds an oxidation catalyst to burn aromatic hydrocarbons, the exhaust-gas component that produces the characteristic diesel smell. It is one of the few efforts to put a reduction catalyst on a production car, not to be confused with the short-lived particulate traps that so far have not been perfected.

The ECOdiesel produces 59 horsepower, a marginal increase from the existing 52-hp VW diesel Jetta but an interesting efficiency gain from what is mainly an emissions control program.

The performance that results is still best described as stately, although VW has long mastered the art of building small, free-revving diesels that lack nothing in throttle response, and the ECOdiesel is pleasantly agile, if not a track-burner.—*Dan McCosh*

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# VAPOR PHASE LUBRICATION: NEW THEORY ON HOT OIL

By JOHN MATRAS

An engine running so hot that it vaporizes its lubricating oil seems a prelude to catastrophe. But a group of researchers at Pennsylvania State University theorize that it is possible to lubricate an engine with oil vapor successfully, opening the door to far higher operating temperatures than ever before imagined.

The discovery intrigues engine designers for several reasons. An engine's radiator squanders a third of the energy in fuel, dissipating it into the atmosphere as waste heat rather than allowing it to be converted into power. But the radiator is necessary to keep the engine operating temperature under control.

"The problem with the lubricants that are available is that if you put too much lubricant in the piston-ring-cylinder zone and the temperature is high—as high as is desired for, let's say, a low heat rejection engine—you form deposits in the piston-ring-cylinder zone," says Dr. Erwin Klaus, professor emeritus of chemical engineering at Penn State. "A high level of deposits generally leads to excessive wear and other problems," such as engine failure.

Ever since the first energy crisis of the early '70s, low heat rejection (or more optimistically, adiabatic, or zero heat loss) engines have been the goal of many engineers working to reduce fuel consumption. However, conventional lubricants were only able to withstand temperatures in the range of 482 degrees F, inadequate for adiabatic engines.

The inspiration for a new technology of high temperature engine lubrication came from an unlikely source. Klaus and his associates at Penn State were working on ways to lubricate the dies used to cast stainless-steel drill bits. Liquid lubricants were causing problems when sprayed on the hot die because of the rapid cooling, which caused heat fatigue.

A solution, first patented by Klaus and Chun W. Lai in 1976, was to apply the lubricant in a vapor phase. The lubricant was heated and carried in a gaseous state to the die, where it was deposited in 5 to 300 molecular monolayers. The high temperatures of the vapor-phase lubricant did not cool the die, and it actually worked better at higher temperatures, particularly in the range of 900 to 1,500 degrees F.

Lubricating with a vapor is fundamentally different from the most common form of lubrication, hydrodynamics, where an incompressible liquid between two surfaces causes them to "hydroplane" over each other. In another study, Penn State's Steve Hsu, using a microscope, noted that during hydrodynamic lubrication asperities, or high points, opposing surfaces under pressure actually touched, causing flash temperatures that created chemical films. Where pressure increased to the point where the fluid thickness was less then the surface roughness, these films became the primary lubricant.

"It is evident," Klaus states, "that the temperatures at the contact point are very high, even though the temperature of the oil going in is room temperature and coming out is not much higher than room temperature. The temperature of that thin film appears to be about 350 [degrees C]"—about 660 degrees F.

"If you follow that notion," says Klaus, "it takes very little lubricant on the surface to do a good job of lubrication. So why not use just the amount you need? The excess lubricant merely becomes sludge, varnish—undesirable things."

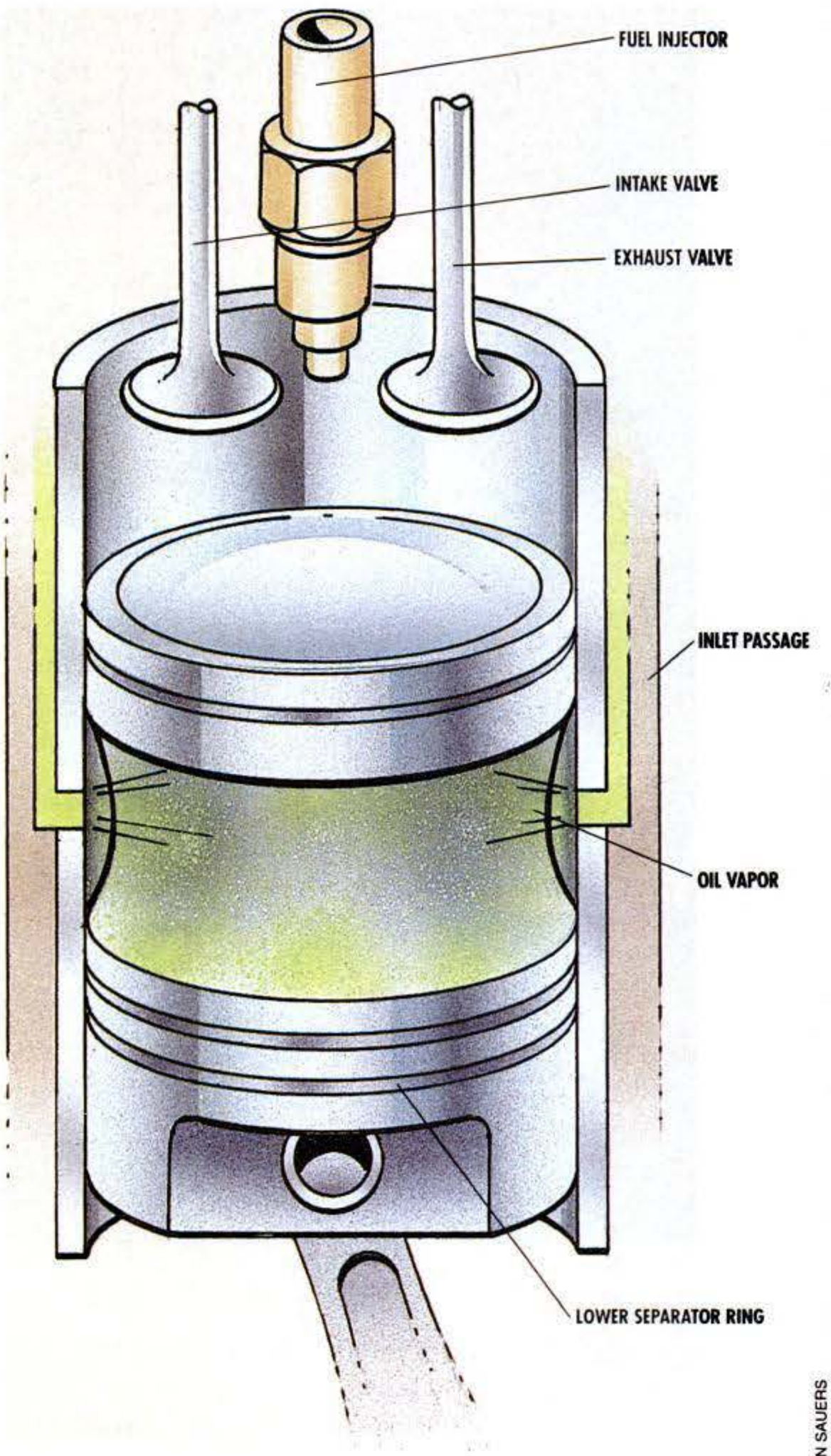
Thus was born the philosophy of vapor-phase lubrication, the product of the simultaneous exploration into fields that are only loosely related. Vapor-phase lubrication essentially preempts the necessity for rubbing action to form the anti-wear layer of chemicals.

Because vapor-phase lubrication needs high temperatures to work, it's particularly attractive for low heat rejection engines. In fact, the anti-wear chemicals don't form well at conventional engine temperatures and are produced best at very high temperatures.

It's always a long way from theory to application, however, and Klaus notes that vapor-phase lubrication is most likely in diesel engines, as designers move toward higher temperatures to meet emission requirements and improve fuel economy.

The vapor-phase lubricant could be delivered to the cylinder wall in several ways: either by injection into the charge air and the combustion chamber through the intake valve, as an additive to the fuel, or below the piston compression ring, through holes in the cylinder wall.

Hot nitrogen gas has served as a carrier for the vapor-phase lubricant in test rigs, but exhaust gas could be used in a production vapor-phase engine. It's available, requires no additional apparatus on the engine, and, says Klaus, is almost instantly up to the temperatures needed. The vapor-phase lubrication would most likely be limited to the upper cylinder wall and ring area. The rest of the engine could, and probably would in early applications, remain lubricated conventionally by liquid lubricants in a pressurized system. Extensive testing is required for such a concept to verify the results and optimize the system. But the promise is great. PS




**An experimental engine uses inlets in the cylinder wall to introduce the vapor lubrication. Production systems could use other means to do the job.**

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improving mileage, developing a lighter fuel tank, and boosting crash safety. The company plans to begin developing a mass-production version sometime in 1995.

The benefits could be tremendous. There would be no carbon monoxide emissions from a hydrogen car ["Clean-Air Fuels for the '90s," Jan. '90; "Sports Car Goes Environmental," Dec. '90]. Nitrogen oxide emissions, however, might continue to be a problem. In addition, if the entire fuel cycle is considered, there are still more questions about the overall environmental impact, because it takes enormous amounts of electricity to produce the hydrogen. A more formidable challenge may prove to be fitting every neighborhood gasoline station with hydrogen facilities.—*Dennis Normile*

## Heavy-duty progress

The big truck in your rear-view mirror, accelerating downhill on a mountain grade, may be less intimidating if some of the advanced technology proposed for heavy haulers becomes widespread.

Heavy-truck engineers are working toward turning a truck cab into a systems cockpit, where the driver programs the desired performance, and computers and related systems do the rest.

Just how far the industry has come is demonstrated by such recent developments as the semiautomatic manual transmission. One by Eaton Corp. replaces the conventional manual gear shift with a hand-sized switch lever. The driver must request all shifts, but these shifts and nearly all clutch operations are accomplished through microprocessor control while the vehicle is in motion. The clutch is used only to get under way.

Such semiautomatics retain the basic durability and torque capacity of a manual transmission while smoothing the often tricky business of engaging the proper gear when on steep grades. Today's heavy-duty diesels are extremely limited in their rpm range, and matching the proper gear can be difficult, even dangerous, on a mountain grade, when a missed shift can result in a runaway in neutral.

Other systems expected to enter the heavy-duty field soon include traction control for trucks, which eliminates wheel spin by monitoring wheel speed and controlling the throttle. Ultimately, according to Eaton, fully electronic braking systems are expected to unify the truck's antilock, traction control, and power-train braking capabilities. PS


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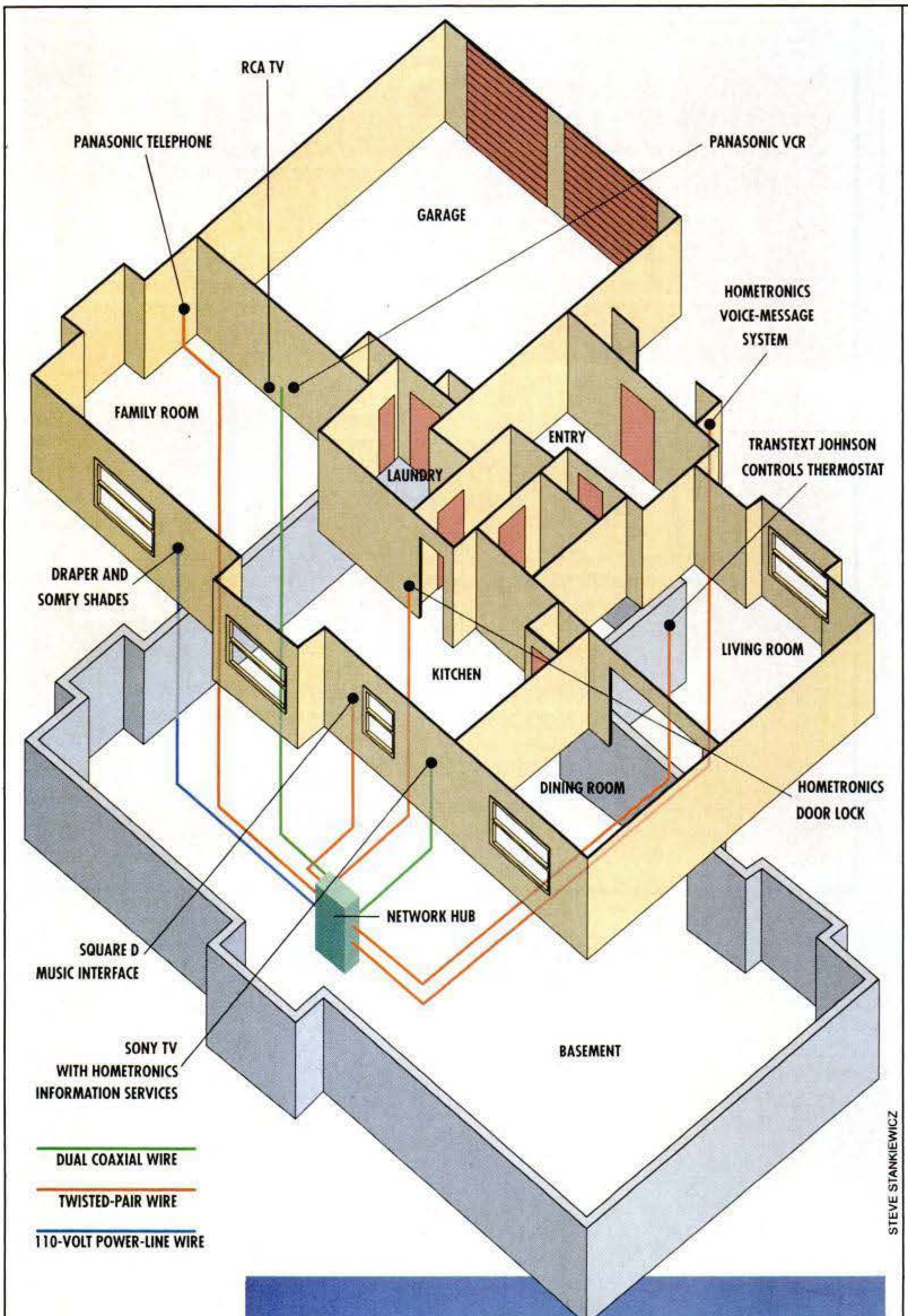
# Home Newsfront

**Edited by MARIETTE DiCHRISTINA**



**A simplified cutaway of the Bright Home (above and right) shows the CEBus "home run" network concept: All wiring meets at a common location, enabling communication among prototype CEBus chips in appliances for house control.**

## Demonstrating smarts

With the Bright Home, the Consumer Electronics Bus (CEBus) effort advances a notch toward reality. The home, opened at the recent Energy Efficient Building Association conference in Indianapolis, is the first to demonstrate prototype CEBus technology to the public.

CEBus is a homeowner's version of the bus technology that allows computers to be networked. In this scheme, however, it's home appliances that communicate and work with one another to provide greater conveniences. With a remote-control unit and a TV-screen menu, a homeowner can program his thermostat as well as his door locks, stereo, and many other switches and settings—without leaving the sofa.

As a standards-setting body, the Electronics Industries Association has worked to develop CEBus. When the standard is completed this summer, however, it will be up to industry to adopt it for use in various products. CEBus is one of two major U.S. efforts to achieve integrated home automation; the other is Smart House, a spinoff of the National Association of Home Builders ["The Integrated, Automated, Educated House," June '90; "The World's Smartest Houses," Sept. '90].

In contrast to Smart House, which requires special new wiring, the CEBus shown in the Bright Home, sponsored by Indianapolis Power & Light Co. (IPL) and PSI Energy, lets you install conventional wiring today to accommodate "smart" products tomorrow. "All you have to do is run the twisted-pair, power, and dual coaxial wires from each outlet to the same place, a panel in the basement," says Mike Coffey, president of Indianapolis-based Hometronics, Inc., which coordinated the companies involved in the home-building project. "We call that wiring 'home runs.'" A modified Elan Advanced Home Automation Network was used as a basis for the wiring ["HNF," June].

Prototype CEBus circuitry in the Bright Home lets appliances hooked to different types of wires communicate (see illustration). For example, temperature information from the thermostat, which is on twisted-pair wire, can appear on the TV, which uses coaxial cable.

The two-story 3,100-square-foot (including basement) house is also energy efficient: It employs extra insulation,



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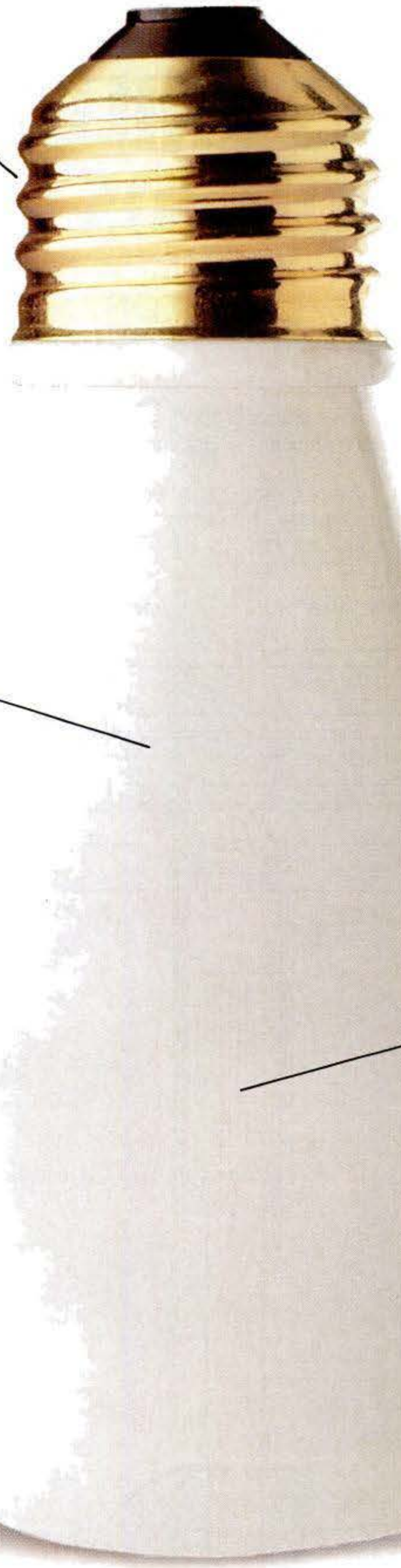

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# REFRIGERATOR MAKES CHILLING SOUNDS

By DAVID SCOTT

Here's the ultimate in cool sounds: a refrigerator that's powered by a loudspeaker and uses no chlorofluorocarbons (CFCs) for cooling.

Researchers at the Naval Postgraduate School in Monterey, Calif., have developed a "cryocooler," a new breed of thermoacoustic engine that cools using sound waves and a mixture of helium and argon instead of the conventional compressor and ozone-destroying CFC refrigerant gas.

When current is applied to a loudspeaker, it begins to vibrate. As the diaphragm pulses outward, nearby molecules compress and heat up. When the diaphragm moves back in, the molecules expand and cool down. In most cases—say, in a room or an organ pipe—the heating and cooling cancel each other out.

The thermoacoustic effect of heat converting to sound was first observed centuries ago by glass blowers, who noticed that the tube attached to a hot expanded-glass bowl would tend to cool and begin "singing." The first demonstration of the reverse of the process—sound used to pump heat for cooling—was in 1982. Now physics professor Steven Garrett and his colleagues at the school, Thomas Hofler, Jay Adeff, and Glenn Harrell, have figured out a way to harness this cycle into an efficient system for refrigeration. Here's how it works:

A small loudspeaker, just like the ones in your home or car stereo system, sits atop a rigid chamber of pressurized helium and argon gas. Plastic baffles—the crucial heat-trapping component—fill the upper part of the chamber. When current is applied to the speaker, sound waves compress and heat up nearby gas molecules. These ram into the plastic, transfer some of their heat, and cool down a bit. After expanding, the molecules end up with less energy and are cooler than when they began the cycle. Heat exchangers inside the baffles pull heat away from the plastic, and the gas inside the chamber gets cold, eventually leaving the bottom of the tube freezing cold.

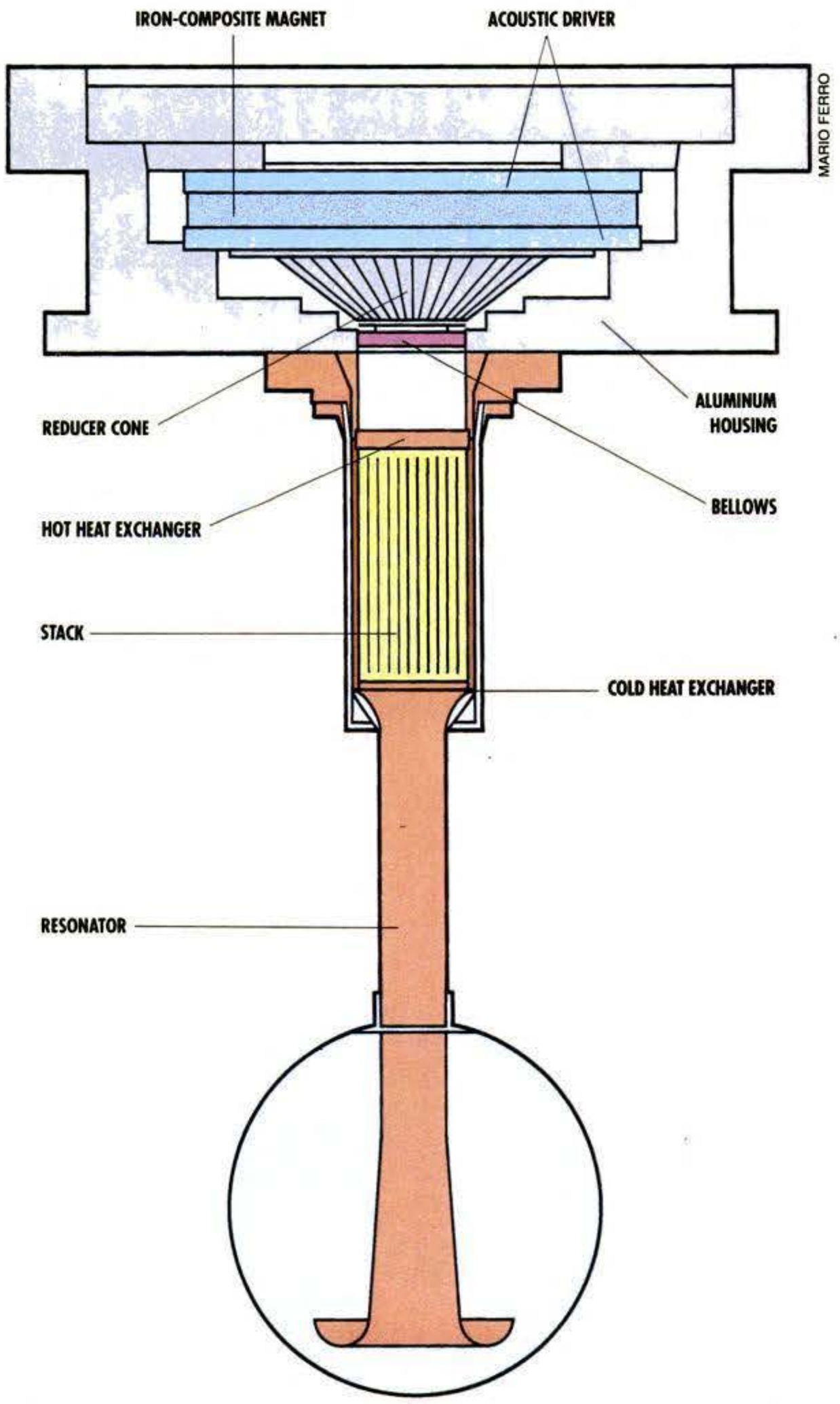
"Basically, what you've got here is a bucket brigade, with molecules passing heat from the gas in the chamber to the plastic," says Garrett. By passing a loop of something like liquid antifreeze over the chamber, the cold can be circulated around the walls of a storage compartment in a refrigerator.

At 160 decibels, the sound inside the cooler is deafening—10,000 times louder than a Rolling Stones concert. But not a sound can be heard outside the system: Because the cylindrical chamber is rigid enough to withstand the static force from the gas it contains at 10 times atmospheric pressure, the chamber won't vibrate from the far smaller additional pressure exerted by the sound waves.

The researchers have already built a number of working acoustic coolers, some capable of producing temperatures of around minus 100 degrees F. One model is even bound for a ride on the space shuttle as early as January next year. Because they have fewer moving parts than conventional cooling systems, acoustic coolers could be well suited to applications on satellites or space vehicles, where efficient, maintenance-free cooling is crucial, says Garrett. And because the coolers vibrate less than conventional ones, sensitive space telescopes wouldn't jump around as much.

Building these cool-sound systems for home use will require some straightforward engineering but shouldn't be terribly difficult, predicts Garrett. The main challenge is designing heat exchangers that will be as efficient as those found in standard refrigerators that use CFCs. The conventional equipment has an advantage because the refrigerant used in the systems also acts as the main heat exchanger. Acoustic coolers, on the other hand, require separate stages: cooling the helium mixture to remove heat from a liquid or gas, which in turn circulates through the appliance. The researchers will also work to adjust the size of the cooling system and the frequency of the sound to find the most energy-efficient combination.

Efforts to adapt the system for home refrigerators and air conditioners are already under way at the Naval Postgraduate School and may be ready for the market in about three years.—*P. J. Skerrett*




**No CFCs required: A thermoacoustic engine in a new refrigerator provides cooling with sound waves and a mixture of helium and argon gas.**



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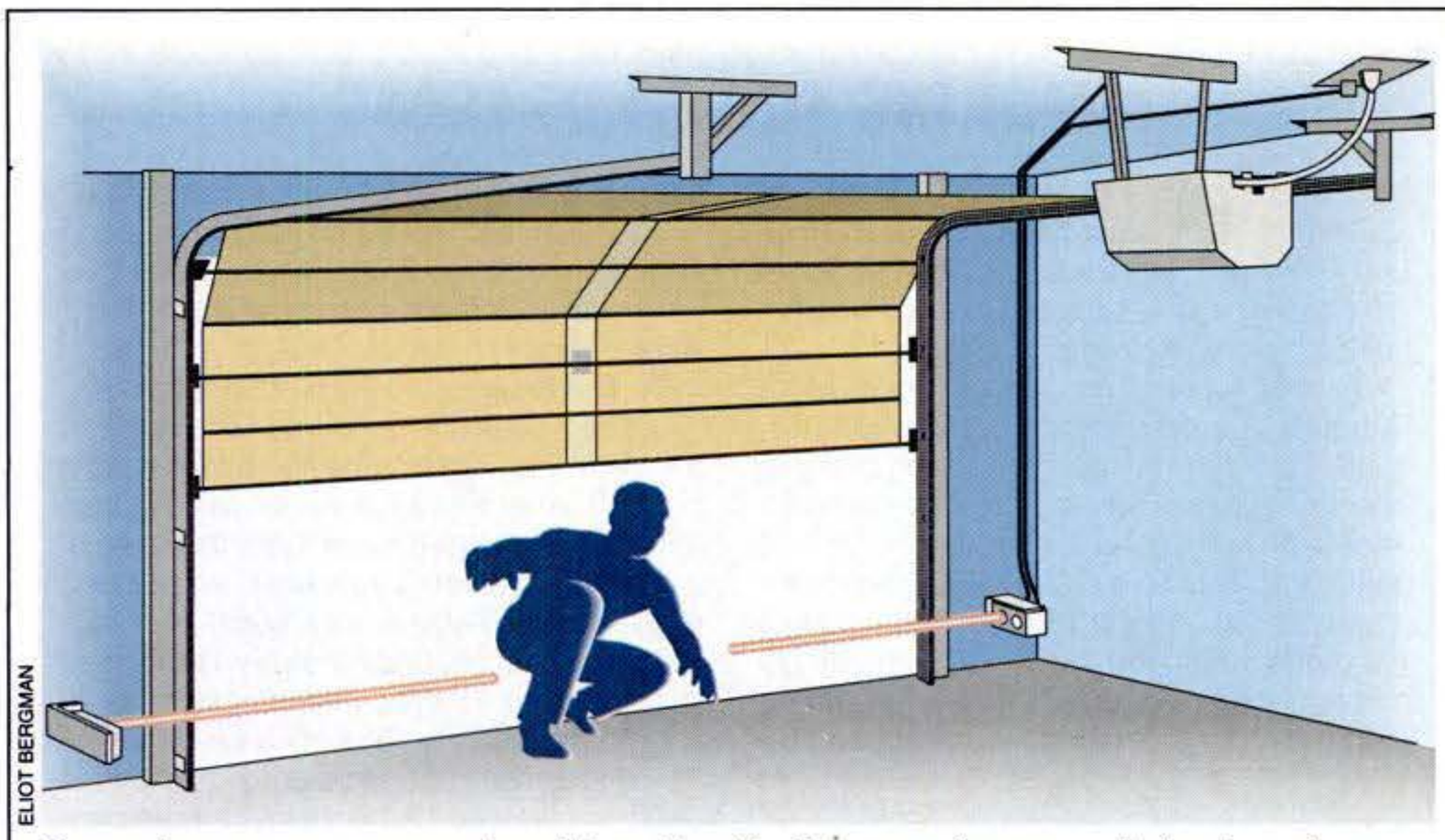

ELIOT BERGMAN

**Garage-door-opener systems such as this one from Stanley stop and reverse a closing door when a beam of infrared light is broken by an object or person.**

efficient lighting and windows, an air-to-air heat exchanger, a variable-speed heat pump, and a fireplace that uses outdoor air for combustion. The house will require 7,955 kilowatt-hours annually for heating and cooling. Similar-size houses in the area can use twice that amount for heating and cooling, says Dwight Klippel of IPL.

It will cost little more to build a CEBus house than a conventional one. "For an average new 2,500-square-foot home, the extra wiring needed for CEBus adds about $700. Then you'd have two more future costs—one for the CEBus panel, which doesn't exist yet but should cost less than $1,000. The other would be for products containing CEBus chips," says Coffey, who predicts that such off-the-shelf appliances, made by various makers, may be available by 1993. IPL, 25 Monument Circle, Indianapolis, Ind. 46206.

## Life-saving garage doors

Seemingly harmless automatic garage doors can be surprisingly dangerous. In a recent eight-year period, 46 children were killed by doors that failed to reverse on contact, according to the Consumer Products Safety Commission (CPSC).

New safety devices detect objects in the path of a closing garage door, stopping the action before contact. A sensor directs a beam of infrared light close to the ground across the garage-door threshold. If the beam is interrupted by something—or someone—the sensor stops and reverses the closing door or prevents an open door from closing.

Beginning this year, all automatic garage-door openers that are sold in the United States must reverse within two seconds after contact with an object or if the door fails to complete its closing cycle in 30 seconds; the doors must also have a quick-release device

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to detach from the automatic mechanism.

The CPSC urges homeowners to inspect garage-door openers regularly for safe operation. To do this, place a two-inch-thick block of wood on the ground under the open door. If the door doesn't reverse upon striking the wood as it closes, disconnect the opener and have it serviced—or replace it with a unit that complies with the new standards.

Non-contact garage-door openers are available as an option from Chamberlain, Craftsman, Genie, and Stanley. If you have an opener made after 1982, it probably can be retrofitted with a non-contact sensor; check with the manufacturer.—*Gene and Katie Hamilton*

## Smoke-stopping foam

Silicone RTV fire-stop foam is neat stuff. You mix a white liquid with a black one, and tiny bubbles begin appearing in the resulting gray ooze. It swells, and in a few minutes, you have fully cured silicone foam rubber.

More interesting, though, is what the foam does. It won't burn or melt, and it tightly seals out toxic smoke and fumes—the Achilles' heel of otherwise fire-resistant construction.

RTV stands for room-temperature vulcanization, a chemical process that occurs when the foam is produced. When two liquid silicone polymers are mixed, the reaction creates a more rigid polymer chain and gives off some hydrogen. This gas expands the foam, which cures to become roughly three times the volume of the initial liquids.

Silicone RTV has been used for several years primarily in commercial and industrial buildings, to seal wire and pipe penetrations in fire-rated walls. Because the foam is costly and not yet required by residential fire codes, its use in houses has been limited so far—but that could change as officials begin paying more attention to smoke protection. The foam comes in liquid-component form from Dow Corning Corp. (Box 994 Midland, Mich. 48686) or in a two-part aerosol can from Insta-Foam Products (1500 Cedarwood Dr., Joliet, Ill. 60435). —*Alex Wilson*

## Architecture and Alzheimer's

While medicine seeks to combat degenerative Alzheimer's disease, careful planning of surroundings can offer some help today. The Corinne Dolan Alzheimer's Center at Heather Hill health-care complex in Chardon, Ohio, is architecturally designed to maximize the independence of people with Alzheimer's. Because 95 percent of the nation's elderly do not live in centers like Dolan, it's useful to know that many of its design principles can be duplicated at home.

When designing environments for Alzheimer's patients, remember that "if you see it, it exists and if you don't, it doesn't," says Chari Weber, Dolan Center director and vice president for special projects at Heather Hill. The center's corridors follow a circular path, providing security while visually prodding resident's fragile memories. For example, ambulatory residents remember to eat when they see food in the cafeteria. To apply this at home, Weber recommends leaving certain foods out and illuminating desirable areas, while darkening areas that the patient should avoid and hiding potentially hazardous electrical switches and appliances.

Other center ideas help patients with incontinence and disorientation. Outside each bedroom, display cases containing personal mementos help residents recognize their rooms. Personal bathrooms have no doors, so residents can see the toilets and remember to use them. Some home care givers successfully move bedrooms across from bathrooms or color-code doors for similar results, says Weber.

"Creating a secure perimeter outside the building is the most translatable feature of the center," says design specialist Margaret Calkins. "The ability to choose whether and when to go outside is important to the confused person's self-image." At home, a fenced-in outdoor area might be one way to provide this.—*Barbara Tunick*

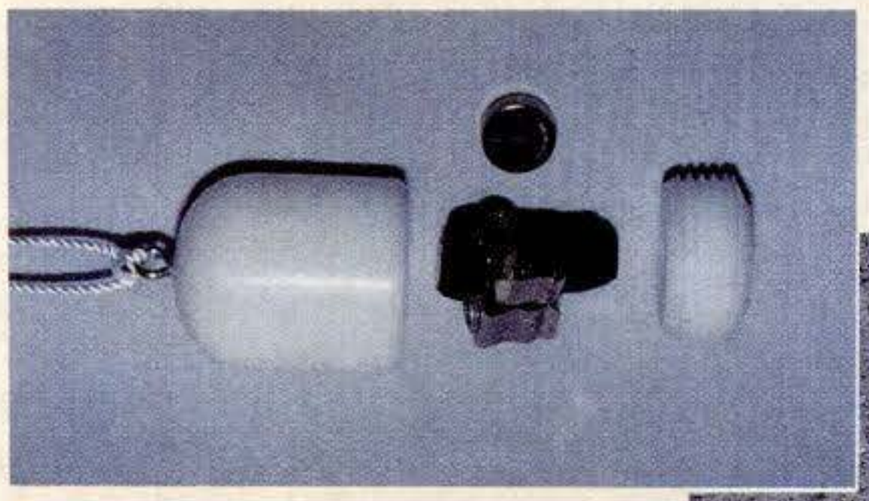
## SMOKING EGG FINDS LEAKS

Of the 223 gallons of water a University of California study says each American uses daily, Richard Rennick estimates that some 40 percent may be wasted through unseen leaks in piping systems.

In 1974 Rennick, now president of American Leak Detection of Palm Springs, Calif., and Jim Ray began working to refine electronic equipment and smoke-detection methods long used by industries to find leaks in plants and by municipalities to locate seepage under streets. Today these methods help find leaks of increasingly precious water around homes as well—and minimize the need to excavate and repair yards when searching for pipe breaks.

"Our services are particularly in demand in drought-stricken areas, where water loss from leaks defeats conservation efforts," says Rennick.

To find leaks up to 20 feet underground, American Leak Detection franchises send an electronic signaling device attached to a plastic filament down a sewer line or drain and track it with a receiver. After the route of the piping system is revealed, a "smoking egg"—a thumb-size smoke bomb filled with inert, nontoxic odorless smoke—is released into the system. "When the smoke finds its way to the surface through a break in the system, the location of the leak is revealed," says Rennick (see photos). American Leak Detection, Box 1701, Palm Springs, Calif. 92263.—*Mary L. Fonseca*



## Odor-eating paint

A new paint from Sweden promises to eliminate the pungent smells of onions, fried fish, and tobacco smoke from the kitchen or other rooms. Outside the home, the paint, called Kefa Odor Control, could freshen the air in offices, restrooms and locker rooms, restaurants and bars, and other public areas.

The dried paint has a microporous coating that absorbs and traps airborne odors. As these gaseous substances slowly oxidize and decompose, they are transformed into an odorless vapor. The inoffensive vapor is ultimately dispersed by normal ventilation.

Indoor climate also benefits; the porous coating absorbs humidity above a certain level and releases moisture as the air becomes drier, thus stabilizing the humidity in a room. Kefa Hightech Corp., 4501 Rowlett Rd., Suite 107, Rowlett, Texas 75088. —*David Scott*

## Notes from home

•A set of three new publications covers aspects of the fire-retardant-treated (FRT) plywood issue for builders and curious homeowners—from testing and



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replacement to legal matters and customer relations. Developed to offer safety and cost advantages over other noncombustible materials ["Lumber That Won't Burn," March '85], FRT plywood used as roof sheathing has been found to weaken significantly under certain conditions ["HNF," Jan. '90]. National Association of Home Builders, 400 Prince Georges Blvd., Upper Marlboro, Md. 20772; $17.

•The 1990 EPA survey of 46,598 homes in eight states, combined with previous years' tests, shows that one in five U.S. homes has radon levels above four picocuries per liter of air—the point at which the agency recommends taking corrective action.

•If water is made undrinkable by a chemical spill, it may not be a good idea to shower in it either. Researchers at Rutgers University of New Brunswick, N.J., have found that the combination of inhalation and skin exposure during a 10-minute shower is equivalent to drinking two liters of tainted water.

## Safer strippers

Could the smelly-fumed, eye-smarting, skin-burning job of paint stripping suddenly have become fun? Not exactly, but new formulations are much easier on you and your wardrobe—as well as on the environment.

Most traditional paint strippers contain up to 50 to 90 percent methylene chloride, a suspected health hazard. New York and California have banned the substance, and the EPA is examining the risks of paint-stripping materials. But now there are at least five methylene-chloride-free brands of strippers available for home use.

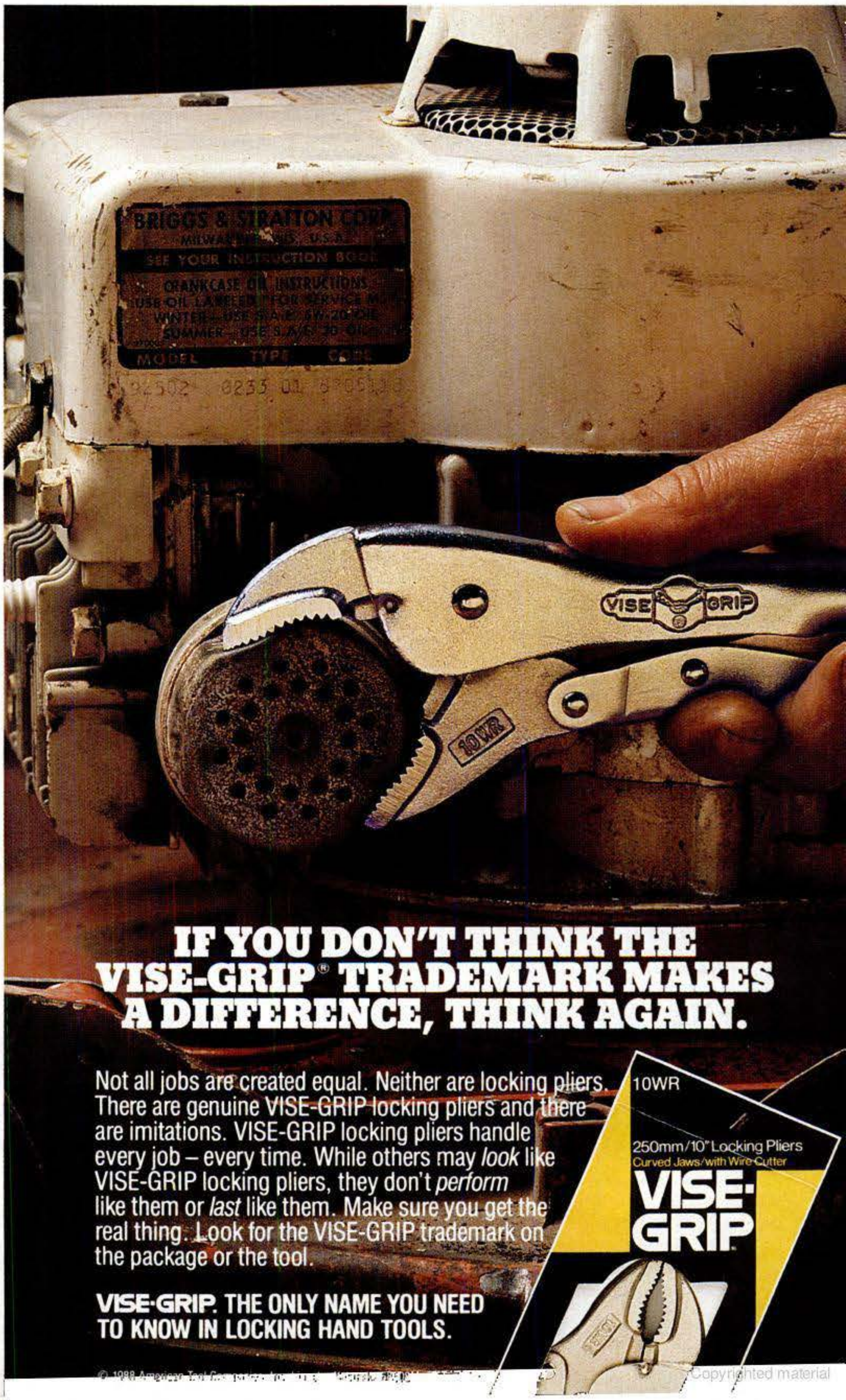
Three of the new strippers use dibasic esters. These synthetic solvents have low toxicity and low flammability and effectively soften oil paint, enamel, latex, lacquer, varnish, shellac, and polyurethanes. Safest Stripper is a nearly odorless white semi-paste. Unlike the others, it isn't recommended for use on fiberglass. Safe n' Easy is greenish, with a latex-paint consistency and odor. Strypsafer is a white semi-paste with a sweet, apple smell.

Smelling of bittersweet citrus, Woodfinisher's Pride uses N-methylpyrrolidone as a slovent. An almost clear gel, it comes in two formulations: One removes varnish, and the second handles other finishes.

Although protective glasses are required and rubber gloves are advisable when using these strippers, you need no special ventilation. Brushes and tools can be cleaned with water. In my trials, I found that the new formulations worked more slowly than conventional ones. On average, it took a half hour to dissolve varnish; latex, one and a half hours; and old oil paint and multiple-coat finishes, overnight.

The fifth stripper, Paint Buster, is different. Available as liquid or semi-paste, it works as fast as methylene chloride strippers and contains acetone, MEK, and toluene solvents. However, the formulation and its tendency to "skin" slows evaporation, making Paint Buster more pleasant to use than the old stuff. It still requires plenty of ventilation and skin and eye protection, and it is flammable. Except for Paint Buster, the new strippers tend to cost more than those containing methylene chloride.—*Phil McCafferty* PS

**MANUFACTURERS OF PAINT STRIPPERS**
**Safest Stripper,** 3M Center Do-It-Yourself Div., St. Paul MN 55144-1000; **Paint Buster,** Nu-Tec Industrial Chemical Manufacturing Co., 422 Harrison St., Bay City MI 48708; **Safe n' Easy,** Dumond Chemicals, 1501 Broadway, New York NY 10036; **Strypsafer,** Savogran Co., Box 130, Norwood MA 02062; **Woodfinisher's Pride,** Creative Technologies Group, Greenville SC 29601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# MAN-POWERED SUBMARINES

"Yeah, it'll kick some water, all right," says Lt. Cmdr. Patrick Poole in the depths of Rickover Hall in Annapolis, Md. In a trice, he and model maker Dale Boyer pounce on a 40-pound paddle-wheel assembly resting on a workbench and hump it into the tail of a belly-up submarine-in-progress.

"Maybe four knots' worth," Poole continues, smiling fondly at his pride and joy, *Subdue*, perhaps the most curious

By PETER BRITTON

PHOTOS BY JOHN B. CARNETT

# TECHNOLOGY RACE



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Popular Science
JULY 1991

The human-powered submarine *SubDude* is launched at Scripps Institute of Oceanography in La Jolla, Calif.

# BENEATH THE WAVES



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*Team Effort* tests the waters in a Tennessee lake; stainless-steel blades provide thrust and directional control.

of this year's crop of man-powered subs.

A few hundred miles due west in Cookeville, Tenn., Ted Haselton figures four knots is child's play. "My boat can go as fast as 8.5 knots," he says with a challenge. Then, grinning, he quickly adds, "Theoretically." Nevertheless, the former submarine captain's otherworldly propeller looks as if it could hit the ceiling, knotwise.

Deep in Southern California, Will Forman disagrees vehemently with Haselton's reading. "He's full of baloney," says Forman. "Anything over six knots'll start a new religion. I'll probably win with only four—and with a standard prop."

Each of these men knows he is right and destined to win at the Second International Submarine Races in Riviera Beach, Fla., this June. So do most of the other thirty-odd entrants from such unlikely places as West Virginia, New Hampshire, Ohio, British Columbia, and England.

The race is organized by the H. A. Perry Foundation and Florida Atlantic University, which is handling logistics and entering a boat. "This year's field is much larger than last year's," says Perry Foundation president Hap Perry. "I think we are going to see an exciting display of ocean engineering and innovation." The two-person flooded (not pressurized) submarines will go head-to-head for nine days.

The submarines are a mix of the arcane, the high-tech, and just plain serious fun, and certain worlds will be watching. The art of human-powered submarine designing, building, and racing is still developing, and the intermix of imagination, physics, materials, theory, and ocean caprice remains up for understanding.

Among the more hotly debated imponderables: What is the maximum speed possible? What is the top horse-

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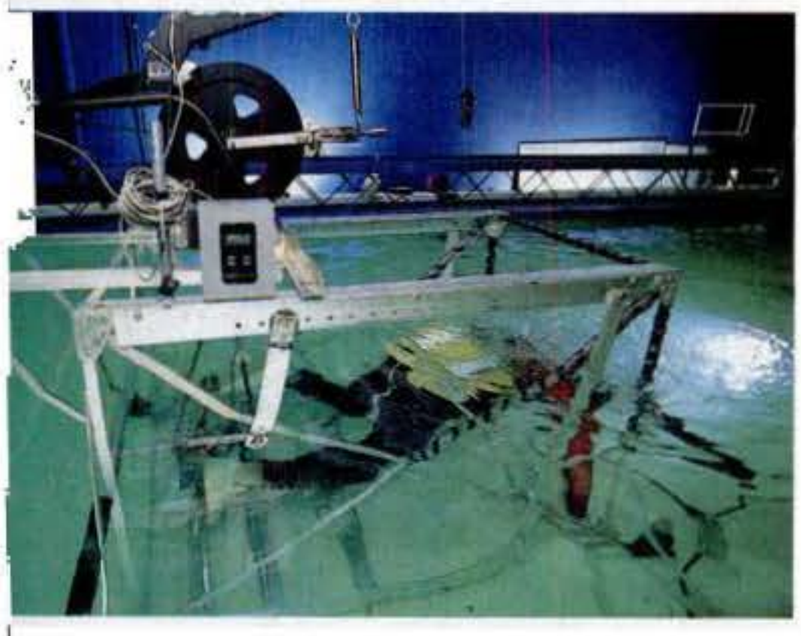
power a human can generate while exercising wildly underwater? What's the best propulsion mechanism: blade, fin, or paddle—or is there some other, as-yet-unidentified plying object?

In addition, there are other niggling details: What are the best shape, skin, and paint? What's the best position for the power source/stroker/propellant/pedaler? And by the way, how do you make a propeller? What's the right size, rpm, material, shape? Are big, thin slow-moving props better than short, fat frantic ones? Is maneuverability more important than speed? Are triathletes better than U.S. Navy Seals and/or Ironmen? What are we doing this for, anyway?

Most of these questions were not answered by the first go-round ["Muscle Subs," June '89]. But several lessons of the 1989 race have left their mark on the survivors. Strength, simplicity, and reliability have been identified as requisites for the hostile undersea environment known as inner space.

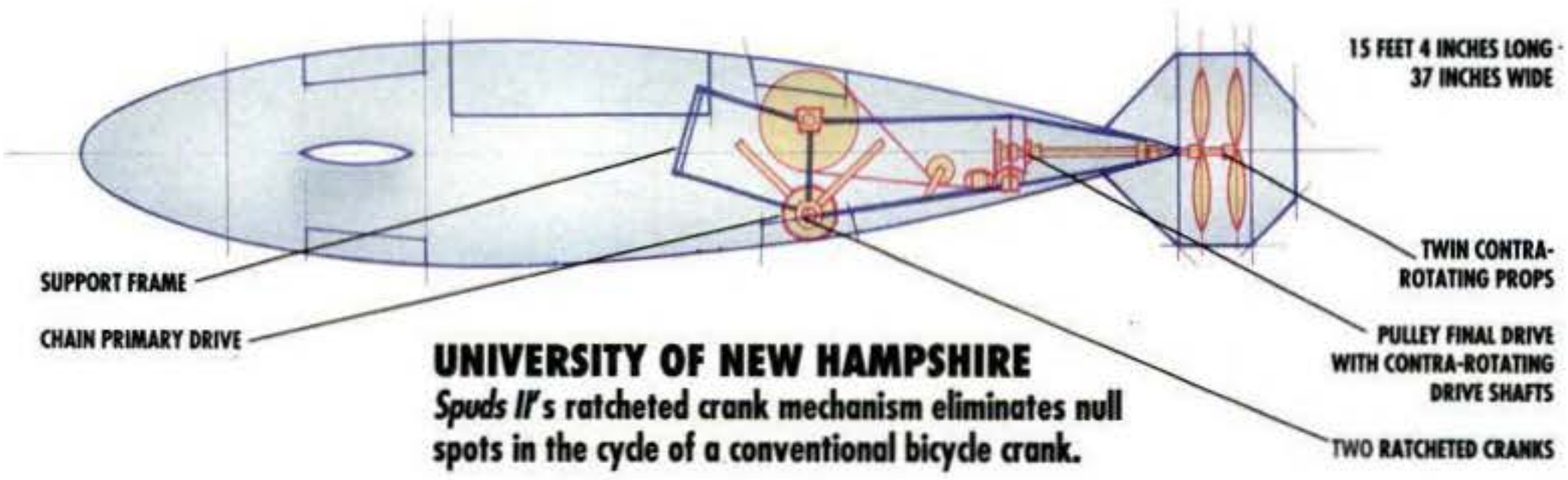
Still, this year's crop of props is divided: About half of the submarines use the traditional bicycle drive/twin-bladed prop design (with more counter-rotators). Others will test the waters in the hope that their innovative, and sometimes radically different, methods of moving through salt water with flair, control, and speed will win the $5,000 grand prize.

In the conservative school, with a 60-inch-diameter 40-rpm prop, is Will Forman, a World War II fighter pilot who is now poised for the trip he opted to forgo in 1989. In late April, Forman's 13-foot-long two-man submarine, *Da Vinci,* was manhandled into the Pacific Ocean off La Jolla, Calif., for its first open-water run. While *Da Vinci*'s sleek killer-whale single-prop shape signals high-tech, its color cries

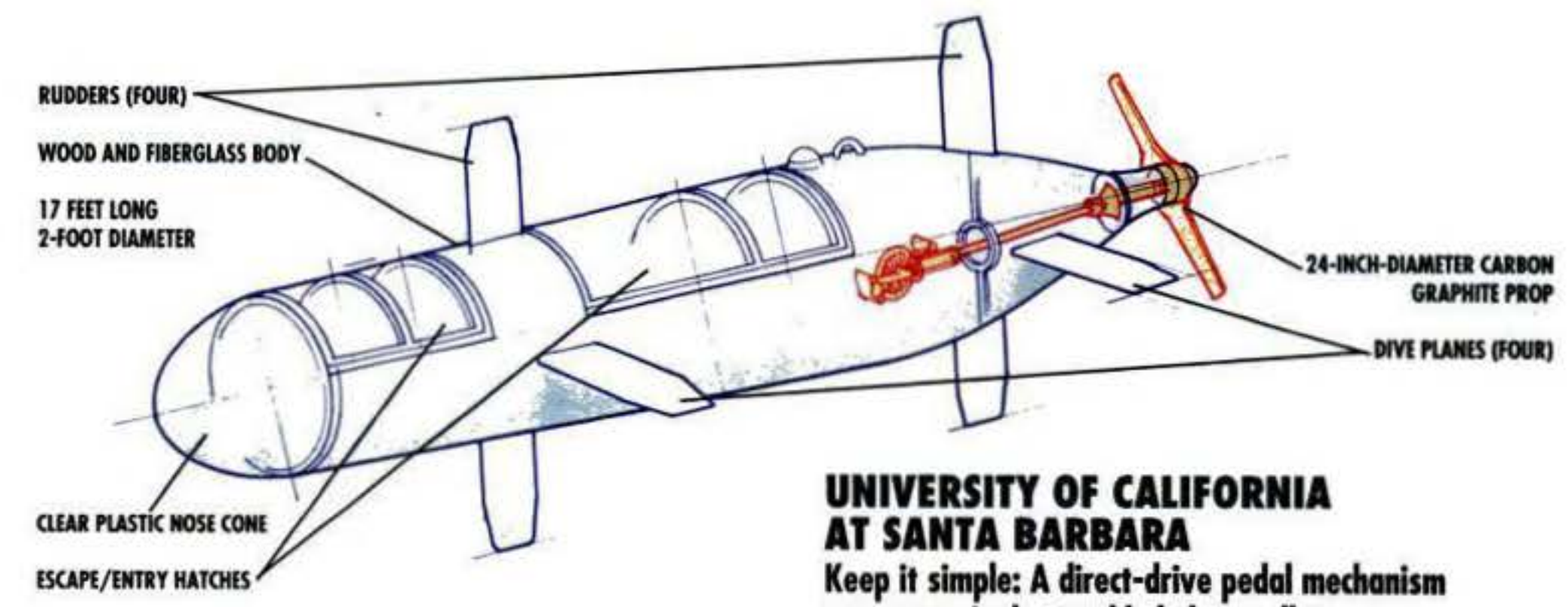


ng page: Lt. Cmdr. Patrick Poole (far
lowers the U.S. Naval Academy's *Subdue*
a test tank. Above: a Navy underwater ped-
tester at Annapolis.

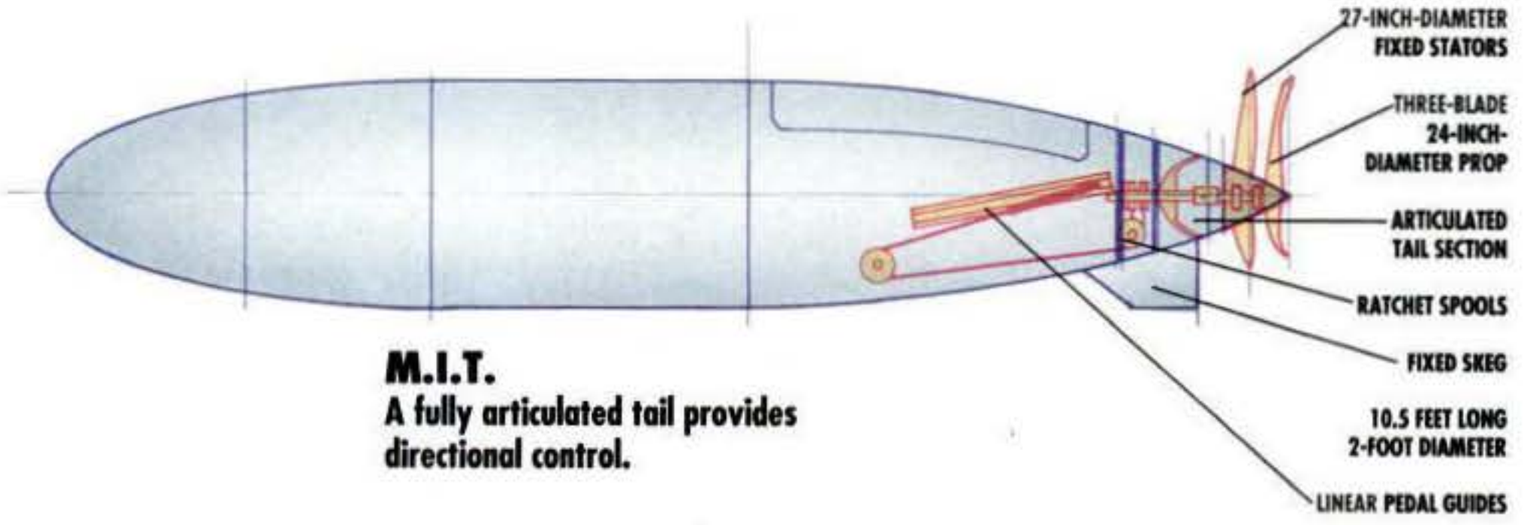
# MAN-POWERED SUBMARINES SAMPLER



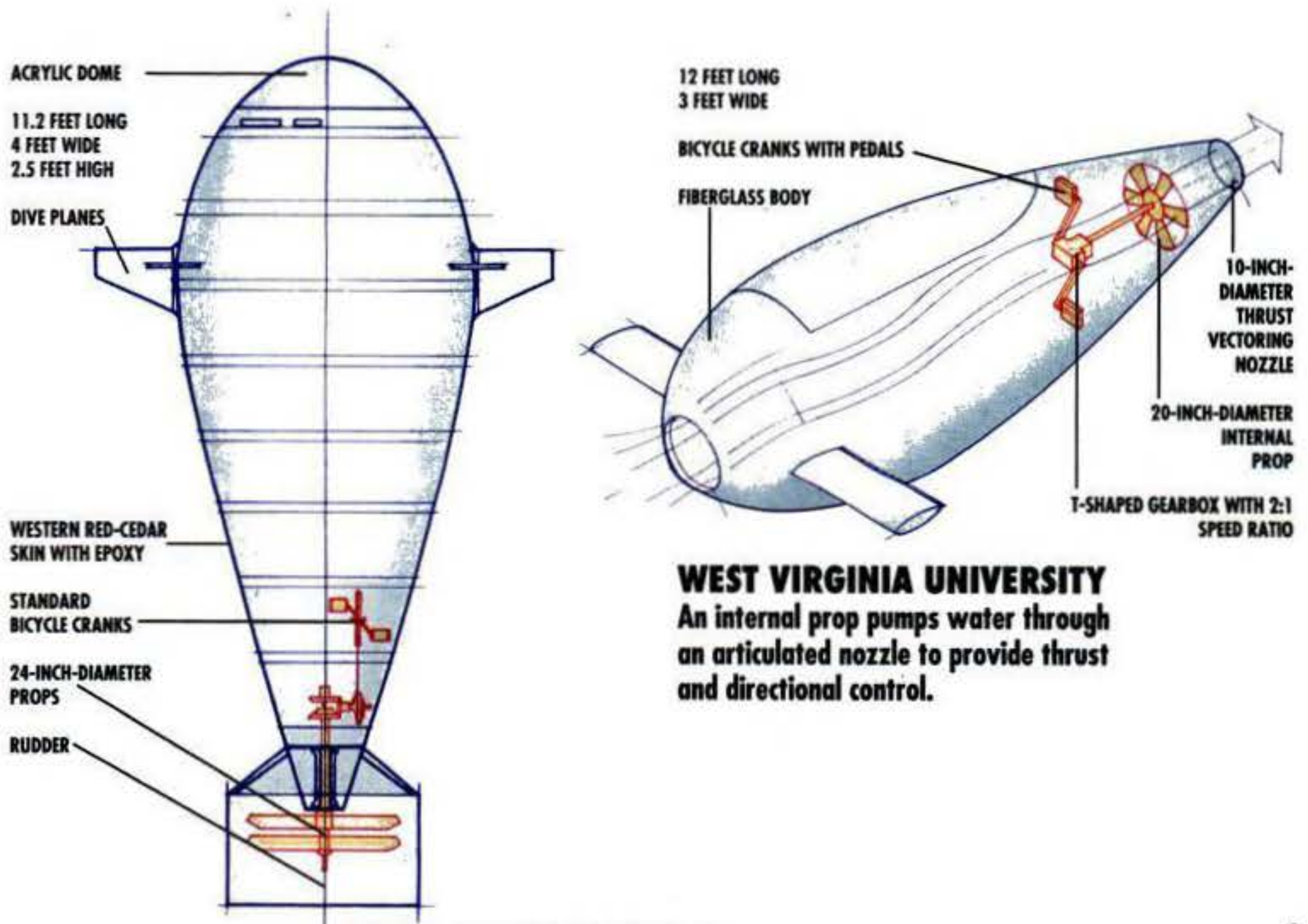

**UNIVERSITY OF NEW HAMPSHIRE**
***Spuds II*'s ratcheted crank mechanism eliminates null spots in the cycle of a conventional bicycle crank.**




**UNIVERSITY OF CALIFORNIA AT SANTA BARBARA**
**Keep it simple: A direct-drive pedal mechanism powers a single two-bladed propeller.**




**M.I.T.**
**A fully articulated tail provides directional control.**




**WEST VIRGINIA UNIVERSITY**
**An internal prop pumps water through an articulated nozzle to provide thrust and directional control.**

**TEXAS A&M UNIVERSITY AT GALVESTON**
***Aggie Ray*'s crew is side-by-side; its contra-rotating props give it an estimated top speed of 3.5 knots.**

JANA BRENNING



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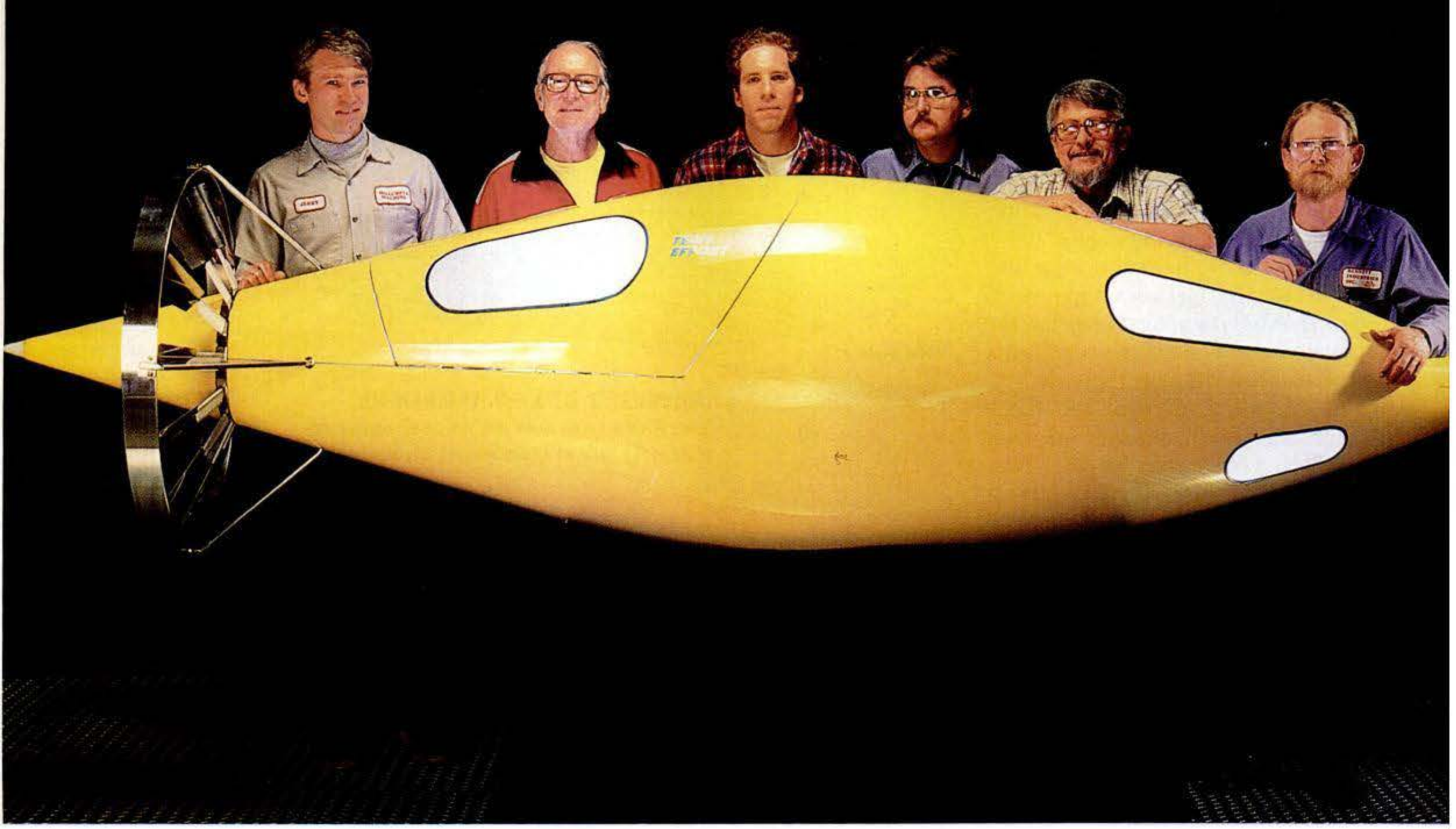

out California-tech. Indeed, the sub's coat of "air-sea rescue fluorescent *caliente* orange killer-colored urethane catalyzed polymer automotive paint" likely would have sent Leonardo through the ceiling and caused Mona Lisa to smile out loud.

"The moon was quartering and the tide dead low," recalls Forman. "I figured she'd be good for at least four, maybe even six knots." The test would also try out his new ballast system. "A major problem [for the contestants] in the first race was control of the vehicle and buoyancy. So we've designed and added a variable buoyancy and ballast contraption."

The human-powered-submarine community is like a family: loving, supporting, and intensely competitive. Even as Forman wrestled with *Da Vinci*, his friend Kevin Hardy and crew, up the coast at Scripps Institute of Oceanography in La Jolla, were adapting Lockheed Corp.'s HPS *Gossamer Albacore* (the first race's imaginative fishtail entry) to accommodate an invention of Calvin Gongwer's called the Aqueon, a patented swimmer-assist device of 1965 vintage. (When he was 55 years old, Gongwer himself once towed a surfer on a board to Catalina Island from the California mainland using the Aqueon.) Gongwer's own spherical sub, *Knuckle Ball,* broke on a reef in the 1989 race; he's now working on the tri-hull ship featured on the August 1989 cover of POPULAR SCIENCE.

Hardy conducted extensive tests of the linkage between the pedaler and the propulsion mechanism. Using the Aqueon, which clamps onto the swimmer's legs, proved tiring for the sub pedaler. Says Hardy: "While our primary thruster remains Cal's horizontal oscillating foil, a new stair-step mechanism has been developed to use with the fins. Roll a pencil between the palms of your hands to see how the shaft moves. That's the basic concept."

In truth, each submarine entered in this competition deserves to have its story told, but four new and remarkable—and quite different—submarines seem to represent the outer edge of the technologies getting ready to hit the beach and wait for the starter's glub.

In engineer Allen Alten's office at Battelle Memorial Institute in Columbus, Ohio, the Anvil 500 graphic design program slowly spins the brightly colored skeleton of the *Spirit of Columbus* this way and that. Team leader Brad DeRoos explains the inner workings of the elegant propulsion system, dubbed an Articulated Linear Thrust Engine (ALTEN, by sheer coincidence), and its attendant flappers.

Alten's beautiful mechanism uses an 18-inch-diameter drive sprocket connected by drive chain to a cable takeup pulley. The pulley-cable ends are attached to the drive shaft, at the end of which are the flappers (two 11-by-25-inch rectangles made of fiberglass and foam). A spring is attached to the crank arm to provide assistance on the return stroke.

"Our basic idea," says DeRoos, "was to look at how various swimming beasts not specifically adapted to swimming—the beaver, otter, duck, frog, even man—swim. The conceit was to incorporate their high-drag/low-drag method of propulsion into a machine."

## WHY DO THEY RACE?

Allyn C. Vine is scientist emeritus at Woods Hole Oceanographic Institute in Massachusetts and creator of the *Alvin*, the submersible that found the *Titanic*. He and Dr. Athelstan F. Spilhaus, oceanographer, inventor, and educator, inspected the Massachusetts Institute of Technology submarine *Icarus* two years ago. Each feels strongly about the worth of the competition.—*P. B.*

**Vine:** "Many years ago, Dr. Columbus Iselin, the second director of Woods Hole, told me about smearing fish oil on the hulls of racing boats. Made 'em go faster. Or, as we'd say today, it decreases drag and turbulence along the hull, thereby increasing laminar flow and speed. It's that kind of practical educational experience you never forget. And that's what the sub races are all about: demonstrating in an indelible way how to design, build, evaluate, and get a project to work—or not work.

"The race shows what's typical of the forefront. It's a rough place. Educating to sea-going reality has its own style of slapping you in the face. Also, the importance of navigation came clear. High tech is fine, but don't get lost. Mistakes here are hard to recover from."

**Spilhaus:** "This competition exemplifies the spirit of pure engineering research. It is a fine thing that will pay off in making young people conscious of the underwater world. Here one can get improvements on old technology and radical new approaches that in the ordinary world would be considered impractical. An example: When the Treaty of Versailles was in effect, the Germans were allowed to have only gliders. This put them ahead in aerodynamics. I like to say that all innovative ideas start as toys. We call them prototypes, but they're toys."



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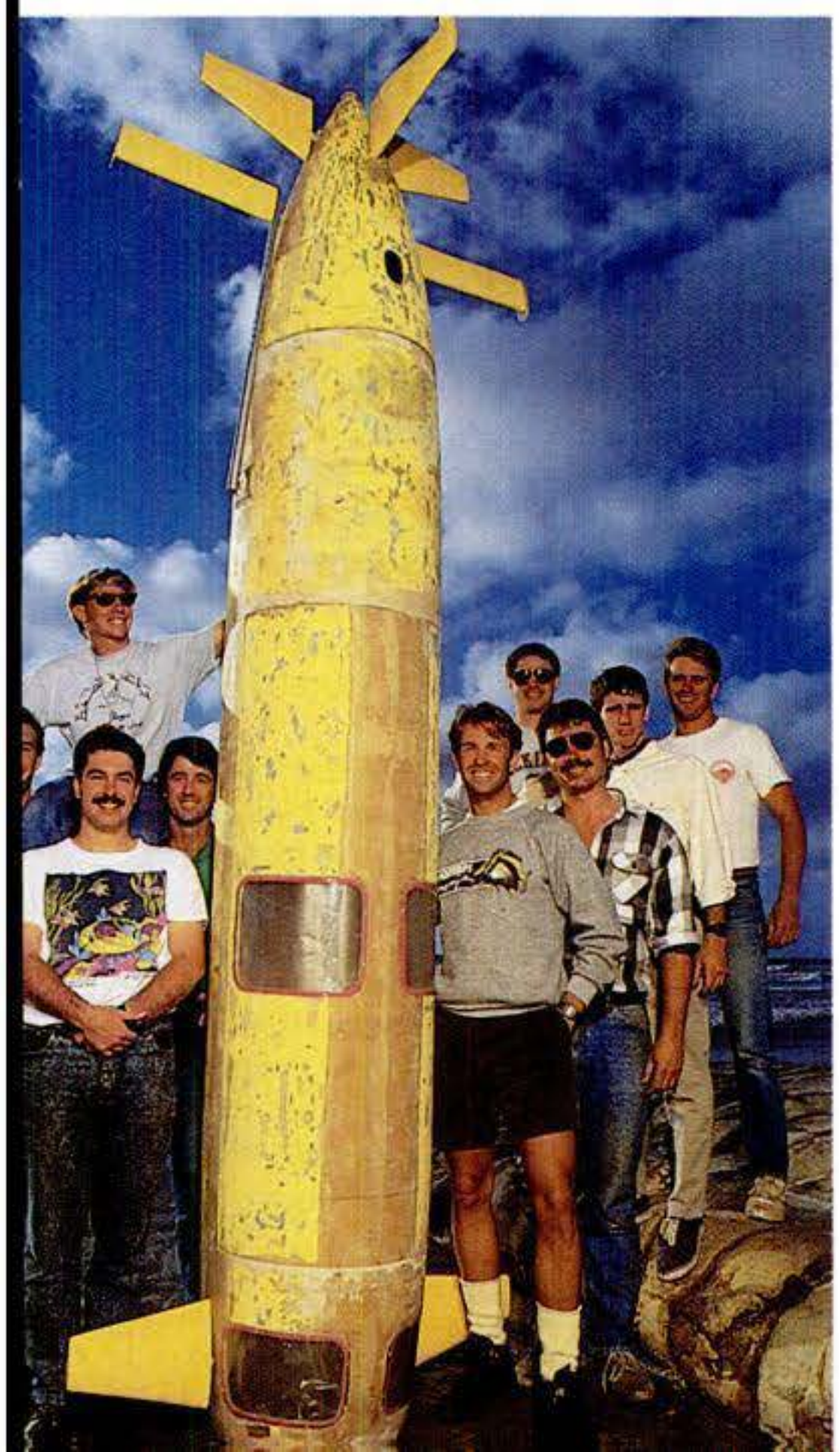
**Facing page: *Team Effort*'s crew with Ted Haselton (second from left) in Cookeville, Tenn. Above: *Da Vinci* and crew on the beach at La Jolla, Calif., with Will Forman at far left. Below: the Scripps Institute of Oceanography team in a playful moment with *SubDude*; Kevin Hardy is closest to the submarine on the left.**



The stroker straddles the bar, facing down, with his feet in biking shoes attached to the pedals. Instead of a circular motion, he uses a nine-inch push-pull movement. One nine-inch push backward spins the small sprocket 2.5 times. This in turn moves the flappers back against the water through 4.5 feet, propelling the craft forward. Pulling forward retracts the flappers, which fold to a 1.5-inch thickness at the start of the return stroke. Riblet plastic film—made by 3M with parallel surface grooves to smooth turbulence—is attached to the outer surfaces of the flappers.

Former submariner Ted Haselton and his team from Tennessee Technological University (TTU) startled the competition with *Nicole's Nickel* in 1989. The laminated and epoxied plywood sub had a six-bladed variable-pitch propeller at one end and no control planes. By changing blade pitch, or angle, the pilot could control the vessel without rudders or fins.

This time TTU has taken a more conservative approach with its entry. But Haselton has formed his own five-man team to use his initial technology even more elegantly. *Team Effort*—backed by Bennett Industries, a Cookeville, Tenn., metal fabricator—has added several degrees of sophistication to an already sophisticated lady. Haselton extended the blade spindles through tubes attached to the hub. The blades can rotate within the tubes. The blade extensions are fitted with freely rotating streamlined fairings; being free to align with the local flow of water, they contribute no thrust but present little drag. The purpose of these adjustments is to enable the prop to operate at peak efficiency regardless of any blade-pitch changes.

Control, in fact, remains one of the race's challenges. This year Haselton's system places control of pitch and yaw (for example, nose up, down, left, right) with the pilot. And for the first time, the stroker has collective pitch control over thrust and torque from his steady 80-rpm output.

Haselton says that in addition to his prop, 60 percent of the hull is the optimal shape to achieve the best laminar flow. Also, the injection of Union Carbide Corp.'s long-chain polymer, Poly-Ox 301, through hundreds of tiny holes around the midsection will reduce drag by another 50 percent. Union Carbide says the polymer is approved by the Food and Drug Administration as a lubricant in toothpaste and as a foam stabilizer in malt beverages. Before *Team Effort* can use the polymer, however, it must be approved by Florida environmental authorities.

The results, Haselton says, are interesting. "Maximum calculations show a theoretical top speed of between 7.5 and 8.5 knots. But don't believe it. I don't. Not yet."

Cliff Goudey and crew at the Massachusetts Institute of Technology (MIT) Sea Grant College Program have come up with a set of new ideas. "This competition has seen a notching up of the state of the art, and rather than go with a revamp of *Icarus* [MIT's 1989 entry], we've taken a new route."

First, MIT's stroker will face aft and use a linear pedaling stroke. But the major difference is derived from considerable prop-thought, says Goudey. The new craft has a three-bladed epoxy-reinforced carbon propeller with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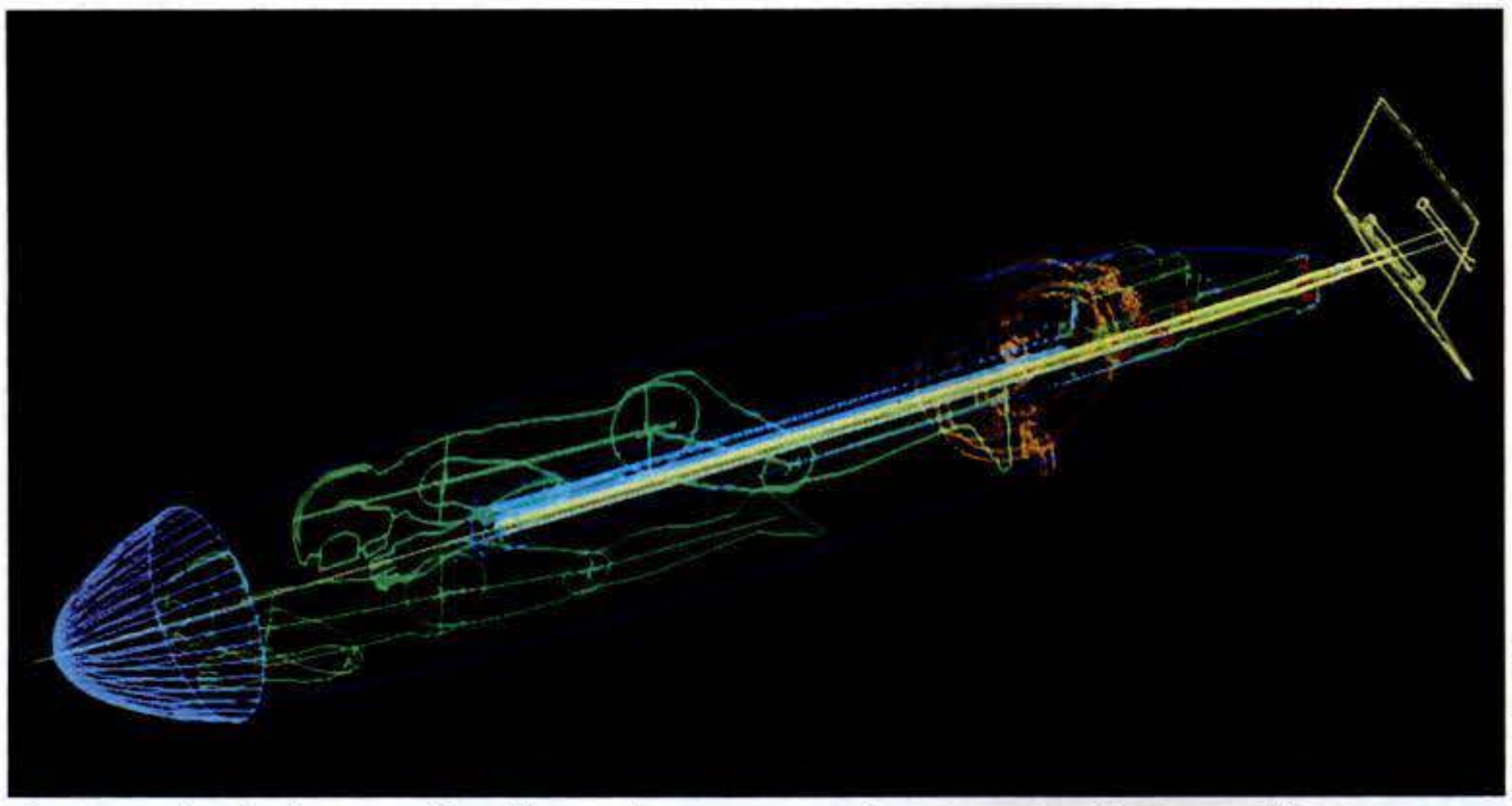


PETER BRITTON

**The *Spirit of Columbus'* articulated linear thrust engine is shown on a Batelle Memorial Institute computer screen at the beginning of the power stroke. (Dive planes and rudder are not shown.)**

a 24-inch diameter. Four inches ahead of the prop is a 27-inch-diameter fixed stator, with blades angled in one direction. The stator induces rotation in a direction opposite to the propeller and acts as a counter-rotating prop without the complicated mechanism. The idea is to impart a swirl or spin to the water before it reaches the prop. This effectively cancels the natural motion imparted by the prop to the sub body, which would throw it off course.

In addition, Goudey's sub will have a fully articulated tail in a ball-and-socket arrangement, eliminating the need for control surfaces. The pilot controls four cables that run through the socket and are attached to the ball at four different places. Pulling the top cable, for example, deflects the tail and directs prop thrust as much as 30 degrees upward; this pushes the stern down and makes the vessel climb.

The middies led this year by Lt. Cmdr. Poole at the U.S. Naval Academy are entering two different submarines, *SQUID* (Submerged Quick Intervention Device) and *Subdue*. In 1989, the original *Squid* captured the grand prize for best overall performance ["Best of What's New," Dec. '89]. Its speed of 2.35 knots was second only to California Polytechnic State University's 2.54 knots. In April 1990, *SQUID* set the unofficial world-record speed for human-powered subs, 3.4 knots over 100 meters (328 feet), in the half-mile-long tank at the David Taylor Research Center near Washington, D.C.

This year's *SQUID* has many changes on the same basic body: The thickness of the shroud around the counter-rotating propellers has been halved; the pedaler has a seat; and control planes have been streamlined. Poole thinks that the craft should do four knots this year. (The nozzle and control planes accounted for 50 percent of the drag in the original boat.) But the big news is twofold: the new craft and a streamlined philosophy of design from Poole.

Months of study by Poole uncovered a major consideration overlooked in boat design. The standard 0.3-hp rating for humans pedaling underwater came from a Navy experimental dive-unit study of endurance. Poole found that

[*Continued on page 84*]

# SPINNING AND BAKING WITH THE BODY BUILDERS

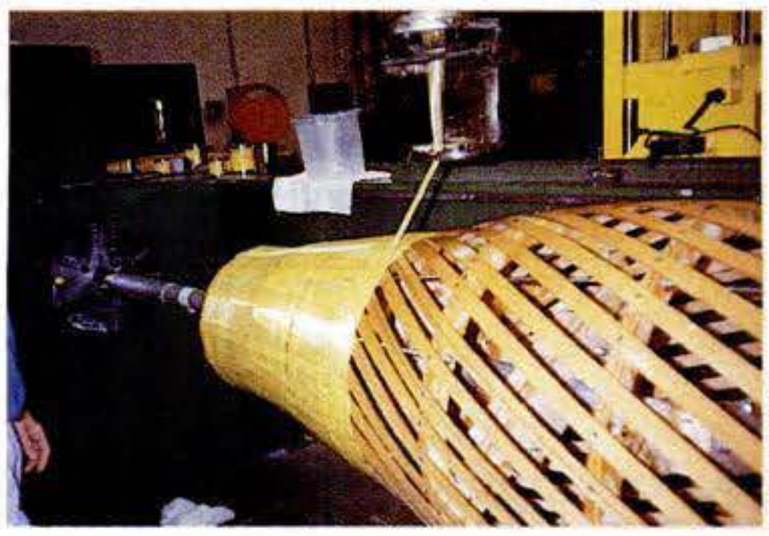
At the Second International Submarine Races, expect the unexpected in the technique of forming submarine bodies. The following two methods were unknown and untested a few months ago.

Former Navy diver Jim Abilla is the student project manager for California State Polytechnic University at Pomona's entry, HPV *Patience* (for his long-suffering wife). In keeping with the contest's spirit of innovation and low-budget cleverness, Abilla and his team found a novel way to make a body.

With a form of plywood strips and hoops already made, Abilla stumbled across a cache of Kevlar 29 yarn on spools, abandoned from another project. By divine guidance, he next wandered into a shop down the road, a company run by Structural Composites Industries. He wanted to see what they did—and hit pay dirt.

SCI could and would do something wonderful: make available its computer-controlled filament winding EnTec (Engineering Technology) machine to helix-and-hoop wind the 1500 Denier epoxy-resin-dipped Kevlar onto the submarine form at approximately 24 inches per second. Two eight-hour wrapping sessions and a final three hour session of winding 20 spools at a time at 12 rpm provided the four helix and seven hoop circuits that were needed for thickness and strength.

After 24 hours of autoclave-curing, Abilla and his team had a bullet-proof golden-colored submarine with structural support built in. In addition, layers of Spectra cloth, used to armor aircraft fuel tanks to withstand .50 caliber bullets, were added for strength in the aft pedaling area. The total weight of the vehicle: 250 pounds.



JAMES ABILLA

PETER BRITTON

**Spinning a body for Cal Poly's *Patience* (top); half of Millersville's *The Hoagie* (above).**

Explains a delighted Abilla: "I maxed out my MasterCard and Visa for good old Cal Poly. And SCI saved the day."

Millersville University team member Chris Bartush's father runs a sign shop in nearby Orwigsburg, Pa., a convenience that proved pivotal in the building of *The Hoagie*. With the proper equipment at hand, the team decided to make its sub's body from transparent 3/16-inch Hyzod polycarbonate. The critical formation would take place in the elder Bartush's Plasti-Vac vacuum oven used to make illuminated signs. The 13-foot 7-inch-long wooden form of half a sub was laid on a composite board with three two-inch-diameter holes bored into it to facilitate the vacuum process. The Hyzod roll, cured of air bubbles for 24 hours in a drying oven, was clamped to an 18-by-10-foot frame above the form. After the wooden form had been heated for 15 minutes, the plastic sheet was placed under the same heating elements. Seven minutes of 300-degree-F heat later, the Hyzod was sagging.

Both were withdrawn from the oven, the plastic quivering over the sub form. Then, whump!, the frame holding the plastic was dropped, and the polycarbonate assumed the sub's shape. A gang of students armed with two-by-fours swarmed over the plastic, tucking in all loose folds.

The vacuum pump tightened the seal and fans cooled the plastic. Moments later, a triumphant crew carried off its near-indestructible creation. A half-dozen more were cast, and the team was ready to bolt the unusual bodies together and install the workings. The final touch would be bright paint on all of the innards: the frame, tanks, and power-transfer system.—*P. B.*



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## The Search For Taste Is Over

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# ANY-SPEED

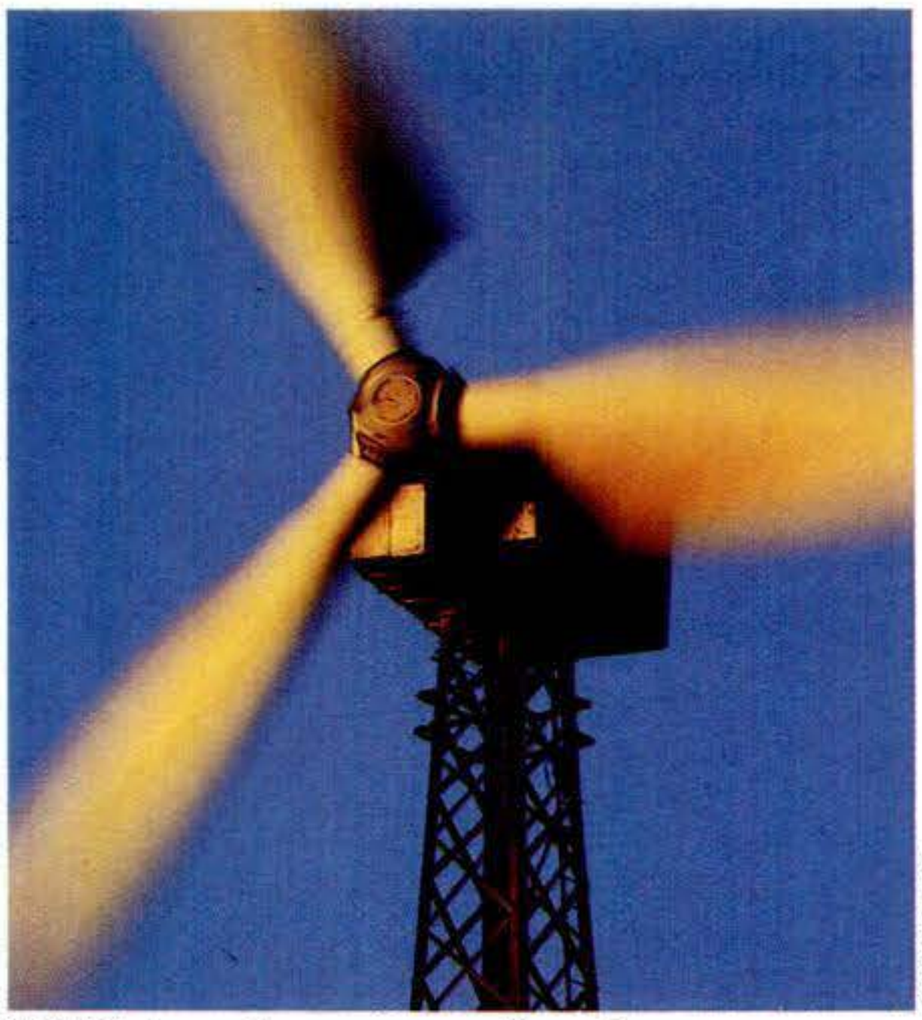
**Most wind turbines govern their whirling rotors' speed to generate electricity compatible with the nation's power grid. A more efficient variable-speed design aims to capture additional energy from gusty winds.**

**By MICHAEL ANTONOFF**

On a nearly calm day in December—off-season for generating electricity in California's Altamont Pass—towers topped with huge rotors bristle from the rolling hillsides as far as the eye can see. Cowboys chaperon a herd of cattle along a drought-parched ridge crowned with a row of becalmed wind turbines. Their blades are motionless or make lazy half-turns in the faint breeze.

In all, a sprawling legion of 7,500 turbines dots the terrain. One of them, a big prototype called 33M-VS, has engineers excited by its potential efficiency advantage over the others. When a gusty wind blows in, a careful observer can pick the test machine out from the crowd. The new rig's rotor speeds up and slows down, while its neighbors continue to spin at a constant rate.

Hence the "VS" in the prototype's designation, indicating that it can operate at variable speeds. The "33M" stands for the diameter of its big three-bladed rotor: 33 meters, or about 108 feet. From the outside, the 33M-VS looks similar to other big wind turbines. The key to its efficiency advantage resides inside the nacelle that houses its generating equipment and in a cabinet of power-electronics circuitry at the foot of its latticework tower.



BILLY EUSTACE

**U.S. Windpower's prototype turbine spins up.**

U.S. Windpower, a major wind-turbine manufacturer in nearby Livermore, Calif., built the 33M-VS to demonstrate that advanced power electronics and improved aerodynamic efficiency could yield a worthwhile increase in electricity generated, says Robert Guertin, the company's vice president of engineering.

The new turbine will soon have a chance to prove itself during the breezy summer months, when it's expected to show an energy-capture ratio (wind-farmer lingo for operating efficiency) at least 10 percent better than the current-generation turbines that are now in use. Peak output could be higher than 300 kilowatts, depending on the wind conditions at the installation site.

According to the California Energy Commission, the experimental wind device should produce electricity at 5.3 cents per kilowatt-hour, making it competitive with power generated from oil, natural gas, coal, and nuclear reactors. The long-term cost may be even lower—if the health and environmental penalties associated with fossil-fuel burning are considered. One recent study suggests that the harmful side effects of traditional fuels add hidden tariffs of three to seven cents per kilowatt-hour.

To earn their keep, utility-grade turbines must generate electric current alternating at a constant 60 cycles per second, or hertz, the frequency of the nation's power grid. But when wind speed picks up, so does the frequency of the current produced by a turbine's generator—a problem that led the designers of most existing turbines to control frequency by keeping the rotor blades turning at a constant speed. When the wind gets too strong, many of these machines use mechanical brakes to limit rotor speed, thus throwing away the extra energy contained in gusts.

It's a strategy that works reasonably well in a steady wind. Yet, as any sailor knows, wind velocity fluctuates most of the time. As a result, the fixed-speed wind turbines are unable to exploit a wonderful fact of physics: Wind power increases proportionally with the cube of wind speed. For example, about 35 percent more energy is contained in a 16-mph wind than in a 14-mph wind. Because most turbines have blades designed for the greatest aerodynamic efficiency in 20-to-30-mph winds, they are unable to make the best use of the energy contained in gusts or higher-speed winds.

The 33M-VS gains part of its efficiency through advanced-design power-electronics circuitry built around a high-power, high-frequency on-off switch called a power transistor. The system automatically reconciles the output of the turbine's twin generators with the utility grid's demand for frequency stability. Similar variable-speed drives have been tried before, but their early-generation electron-



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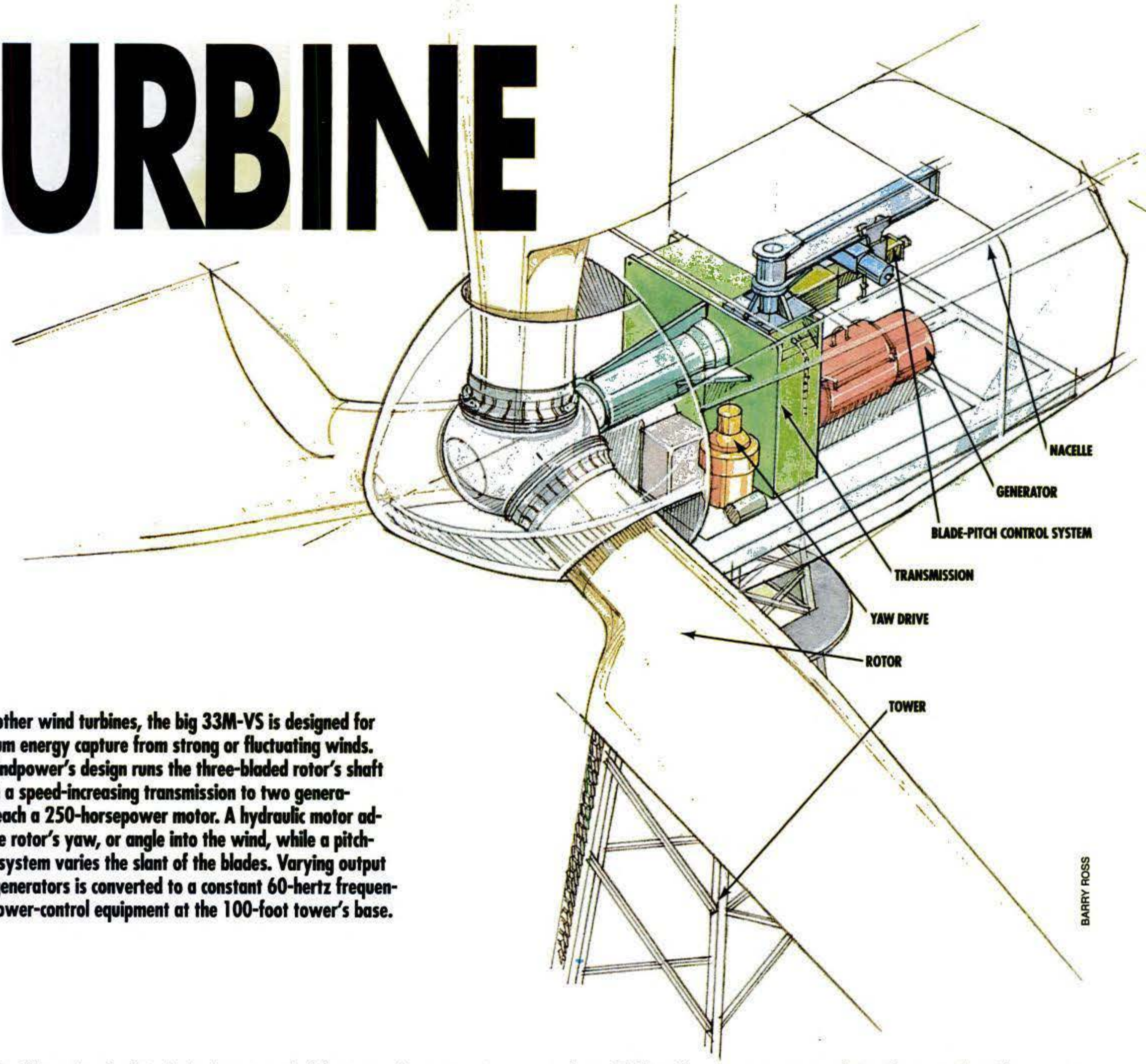
# TURBINE




**Unlike other wind turbines, the big 33M-VS is designed for maximum energy capture from strong or fluctuating winds. U.S. Windpower's design runs the three-bladed rotor's shaft through a speed-increasing transmission to two generators—each a 250-horsepower motor. A hydraulic motor adjusts the rotor's yaw, or angle into the wind, while a pitch-control system varies the slant of the blades. Varying output of the generators is converted to a constant 60-hertz frequency by power-control equipment at the 100-foot tower's base.**

ic controllers tended to inject unwanted harmonic currents into the power grid.

As wind speeds rise and fall, U.S. Windpower's new controller intervenes, first by rectifying the generators' variable-frequency alternating current to direct current, and then by inverting it back into current alternating at a smooth 60 hertz. Finally, the current passes through a step-up transformer on its way to the utility grid. The big turbine also is able to adjust the angle of its blades to maximize the efficiency of flow over the airfoils as wind speed changes, while limiting structural loads on the mechanical parts. Lower loads mean these components can be lighter weight and longer lasting.

A large portion of the effort invested in developing the power controller went into writing custom software that enables the turbine to run itself, while making electronic and blade-pitch adjustments to achieve the highest energy capture from the changing winds.

The 33M-VS prototype was erected in 1989—just in time for the Loma Prieta earthquake in California. Though the structure wasn't damaged, a "windsmith" (wind-turbine technicians wear this trendy handle) working at the top of the tower was shaken up, recalls Louis Manfredi, senior test engineer for U.S. Windpower. The newly developed power electronics were installed last December. Following a program of testing and refinement, the company expects to install approximately 30 production versions of the turbine by the beginning of 1992, mainly at sites in California.

Serendipity is a factor in situating wind-powered generators. For example, peak electrical demand among customers of Pacific Gas & Electric Co., the northern California utility that buys the output from the wind farms, occurs in summer, when people are most likely to be running their air conditioners. It's also the height of the wind season in the Altamont Pass.

A pair of the advanced machines are scheduled to be placed on the eastern shore of Lake Ontario, where they should be well matched to the wind levels and power-usage pattern, says Gerald Rockower, creative services director for Niagara Mohawk Power Corp. in Syracuse, N.Y. Peak winter heating needs in that region happen to coincide with the strongest winds of the year blowing in from the Great Lakes.

What further refinements may be made to wind turbines? Guertin believes that there will eventually be an opportunity to build in some artificial intelligence. "We are looking at giving the turbine adaptive control based on sensing wind conditions and on what it knows about its historical power output," he says. "It may be able to finely adjust its operating parameters to maximize output and minimize mechanical loads." PS



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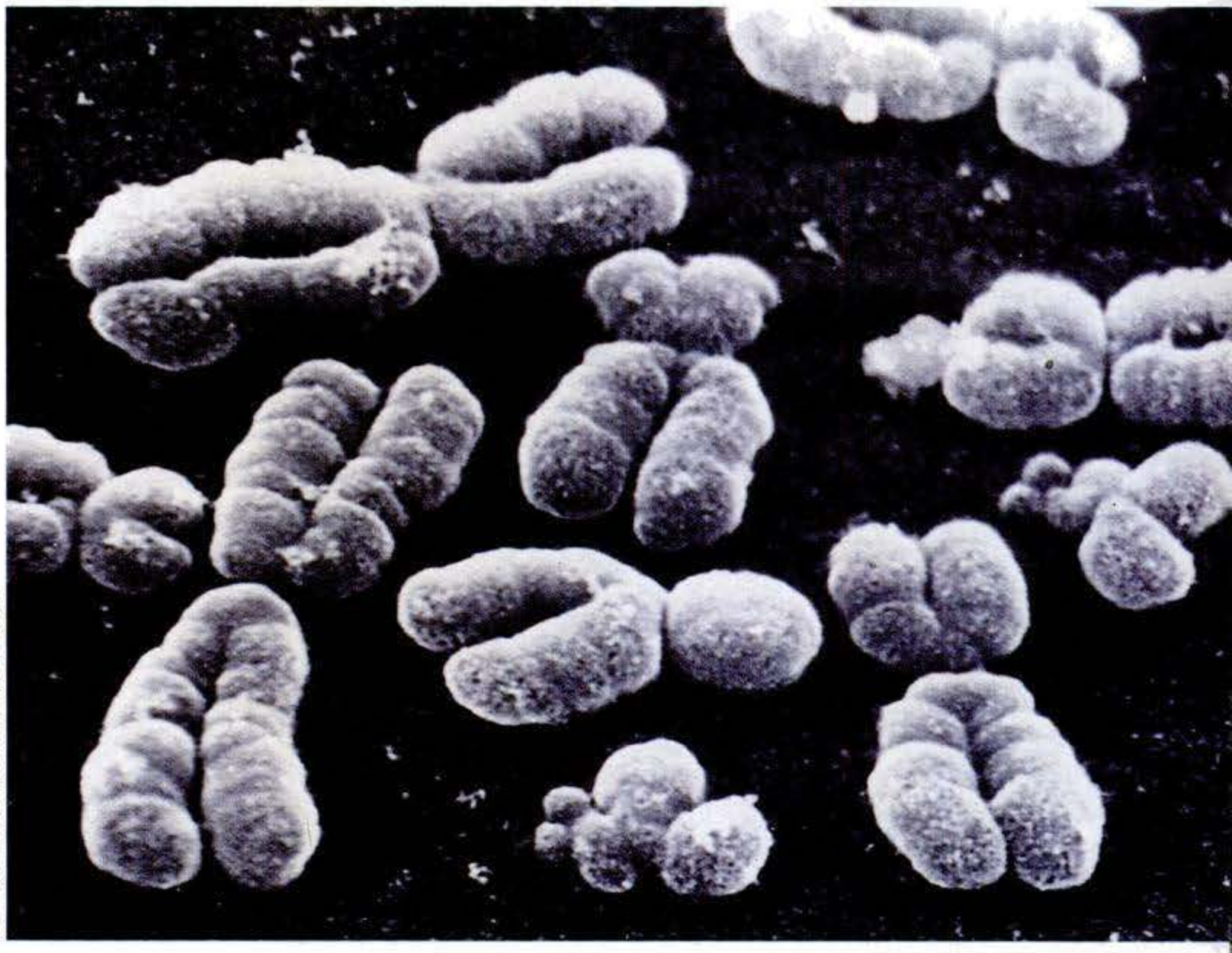
**The human genome project will cost at least $3 billion and take 15 years. Its aim: mapping all the genes in the human cell to provide a key to the vast book of life.**



BIO PHOTO ASSOCIATES / SCIENCE SOURCE

# GENOME

**By EDWARD EDELSON**

Geneticists Raymond White and Francis Collins were beaming when they stood before television cameras last July. They had just discovered the gene that causes neurofibromatosis, the famed "elephant man" disease.

The smiles broadened a month later when workers in White's lab said they had learned that the newly found gene was identical with one that seems to play a role in many human cancers. At one swoop, genetic research had given an insight not only into a brutally disfiguring disease but also into one of the leading killers.

The TV cameras rolled again the following month at the National Cancer Institute in Bethesda, Md., when Steven Rosenberg and his collaborators announced they finally had permission to try gene therapy to cure a usually fatal disease. Within hours, they were injecting genetically altered cells into a five-year-old girl who had been born with a seriously flawed immune system.

And just a month later, researchers said they had done test-tube studies in which they had corrected the cellular defect that causes cystic fibrosis, the most common genetic disease among white Americans. The cystic fibrosis gene had been discovered only a year earlier, and now research opened the possibility of a near-normal life for patients whose survival once was counted in terms of a few painful years. Weeks later, Rosenberg and his collaborators started a second gene therapy trial, this one for patients with terminal malignant melanoma, a particularly vicious skin cancer.

All these advances were based on one achievement: the identification and isolation of specific human genes. Impressive as the results seem now, leaders of America's genetic research community say that they are comparable to Henry Ford making cars by hand, one at a time. Geneticists have an assembly-line plan they say can revolutionize not only genetic science but all of medicine. It's called the human genome project, and its goal is nothing less than the mapping and isolation of all the genes in the human cell.

It's inefficient to continue today's fragmented approach, these geneticists say. Collins, at the University of Michigan, and White, at the University of Utah, had to work for two years to find the neurofibromatosis gene. The estimated cost of discovering the cystic fibrosis gene is tens of millions of dollars. Genetic discoveries will be made a lot faster and cheaper once the genome project gets rolling, its proponents say—and it will have many other major benefits as well.

"The Human Genome Initiative will give us two things," says Leroy Hood, a world leader in genetic research at the California Institute of Technology in Pasadena. "It should promote technological development of instrumentation the likes of which we've never seen before, and it's going to give us this encyclopedia of life. That isn't an experiment. It's a resource. It's going to be in a computer, and it's going to let biologists do all sorts of fancy things thereafter."

There's a glimpse of Hood's dream of the future in the laboratory of Glen Evans, a molecular biologist at the Salk Institute for Biological Studies in La Jolla, Calif. Evans is one of many bright young scientists bursting with ideas about how to map the genome, the term for all the genetic material of a species. In his laboratory, you can watch a machine, a simpler version of a laboratory robot that Hood invented, go through a set of tedious movements that once would have been done by a



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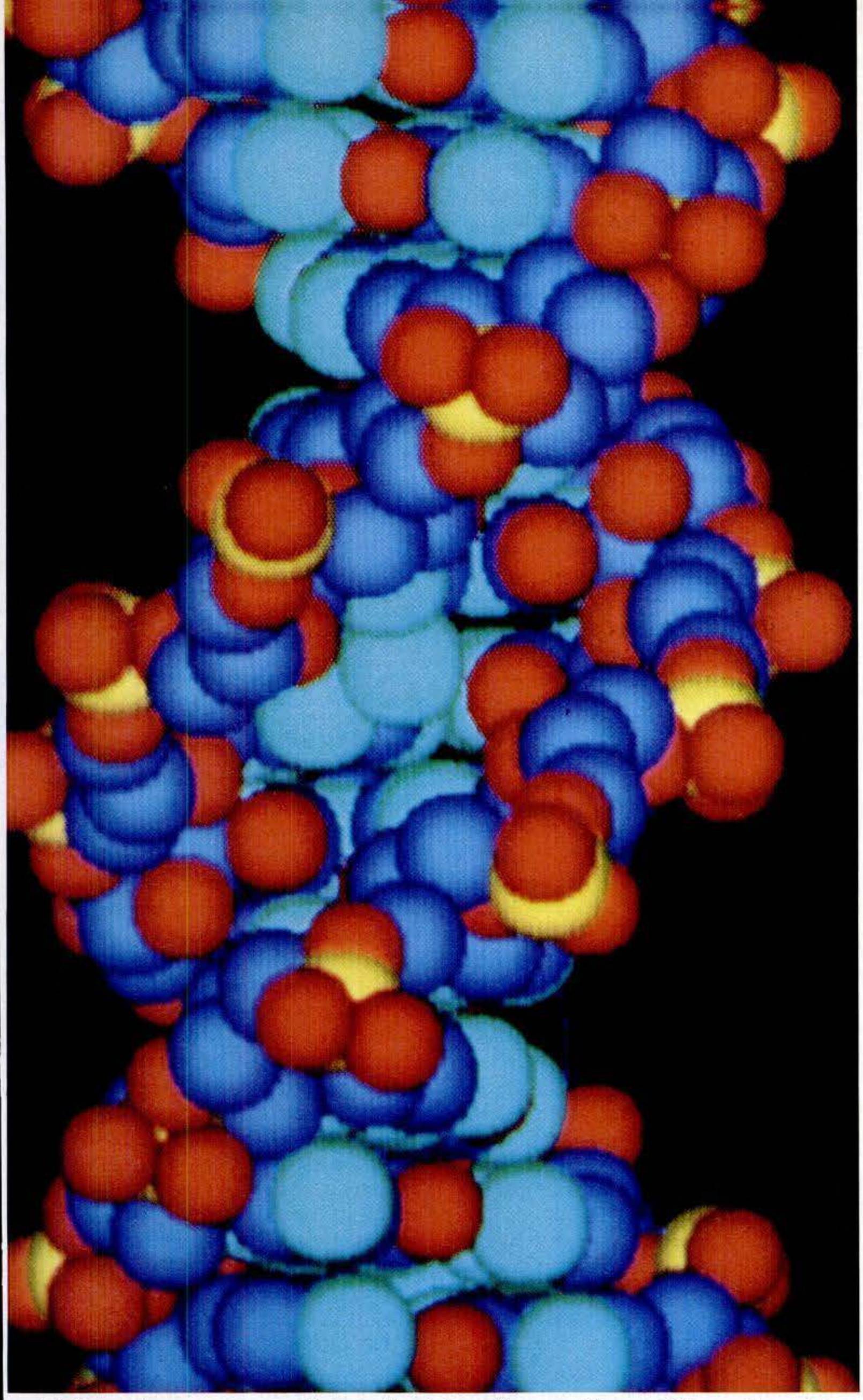

WALTER GILBERT / PETER MENZEL

**Left: human chromosomes seen with a scanning electron microscope. Above: a DNA computer model.**

technician. It can literally build a gene, unit by unit, by following computer instructions.

"We just type in what the sequence is, make sure all our bottles are filled, and come back three hours later," Evans says. "This is the cheap version. It costs about $12,000, as opposed to the robot, which is about $30,000."

Evans quoted a few other prices: a microscope that lets him see genes directly, $20,000; a micromanipulator that lets him slice out a section of genetic material, $15,000. But his dream machine—another instrument that came out of Hood's laboratory—is one that can read the gene sequences automatically. "It's incredibly useful, but we don't have it. It costs $100,000. When we have to determine a sequence now, we do everything by hand. If I had an automated sequencer, I could do the same thing but in a much more efficient way." The human genome project would give him—and others like him—those tools.

Hood and Evans are fervent believers in biology's first megaproject, an effort that will cost about $3 billion and run for at least 15 years. But there are equally fervent opponents. The human genome project has aroused strong emotions on both sides, and those emotions are growing stronger as the program picks up speed.

Feelings range from the awe expressed in the description of the project by Walter Gilbert of Harvard University, a Nobel laureate in genetics, as the "Holy Grail" of biology to the curt dismissal of the program as "mediocre science" by Martin Rechsteiner, a biochemist at the University of Utah who is spearheading opposition to the plan. There are also worries that the project could lead to a twisted 21st-century version of Nazi eugenics, in which people are stigmatized for the genes they carry. Counterbalancing those fears are hopes that the genome project could bring medicine unmatched abilities to ease and improve the human condition.

Hood and other geneticists say the injection of some serious sums of money now will bring rewards of incalculable importance and benefit to humanity.

"To get the human genome is priceless," says Norton Zinder of Rockefeller University in New York, who chairs the National Institutes of Health (NIH) advisory committee on the project. "It's worth more than a lousy aircraft carrier, which is five billion dollars. Just to have the genome—what can you compare it with?"

"Why do we want to spend the money?" asks James Watson, the Nobel laureate who is heading the project. "The answer is there is no better way to understand anything in biology than to go straight for the gene that's involved. We have an example of that in cancer. Only when it became possible to isolate the genes that cause cancer could we understand what went wrong."

Behind those statements is a belief that genetics is ready for a mighty leap forward—that biomedical technology is building the tools that make possible a complete understanding of our genetic inheritance at a reasonable price.

It's a peculiar territory they're exploring: a ribbon of a molecule called DNA—deoxyribonucleic acid—two yards long and a few microns wide. You've got that much DNA in almost every cell of your body, divided into 46 units called chromosomes. You inherit them in pairs: 23 from your mother, 23 from your father. Every time a cell divides, the two daughter cells get a full complement of chromosomes.

The DNA that makes up those chromosomes consists of two matching strands coiled in a helix—a discovery that won Watson his Nobel Prize. The immensely long DNA molecule is made up of subunits called nucleotides, or bases. There are just four different


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bases in DNA, named cytosine, guanine, adenine, and thymine, usually referred to by their initials. In the two DNA strands of a DNA molecule, a C of one strand is matched with a G in the other and an A is matched with a T (see illustration opposite page).

There are some three billion bases in the human genome; somewhere in that long thread are sequences of bases that code for all the proteins that make life possible. Each sequence is called a gene, and the best estimate is that we carry from 50,000 to 100,000 genes in each of our cells.

Molecular biologists have made incredible advances in manipulating this system. They can snip the DNA molecule to cut out a gene and put it into bacteria, where it busily turns out its protein. Voilà, the genetic engineering industry, which has made many a molecular biologist a millionaire.

Using the machine invented by Hood and his colleagues, biologists can make their own strands of DNA, working either with genes or probes to find matching strands. Yet with all their advances, they've barely begun to get the kind of information about the human genome that they want.

"The catalog of all the human genes we know anything about has just gone to press with its ninth edition," says Victor McKusick of Johns Hopkins University in Baltimore, the man who keeps the catalog. "The number is 5,000. There's a long gap there between 5,000 and 50,000. And the total number of genes mapped to chromosomes is only 1,900."

Most of the genes mapped so far are those that cause disease. And mapping isn't cheap. "Obviously, it's not cost effective to do genes one at a time," Zinder says. "If we ever get the whole map done, any time you're interested in a gene you could reach in and get it."

When Zinder says "the whole map," he's talking about two separate things, a physical map and a genetic map. The two maps give you different kinds of information about the genome, are drawn by strikingly different methods, and require different vocabularies.

A genetic map locates genes in relation to one another on a chromosome: Gene A comes before gene B comes before gene C. Biologists have been mapping genes—first to individual chromosomes, then to general regions on chromosomes—for half a century.

A basic technique for making genetic maps is based on nature's sloppiness. When a cell divides, the two strands of DNA in each chromosome separate so they can duplicate themselves. That separation is often flawed. The threads of DNA keep breaking and recombining with other threads. Thus you can tell how close together two genes are by noting how often they become separated by this sort of recombination.

A newer way to map a gene makes use of restriction enzymes, which clip DNA at places where the enzymes recognize specific base sequences. (Bacteria use restriction enzymes to attack invading viruses. Biologists have isolated a bunch of bacteria as tools for chopping DNA into useful segments.) Their use in gene-finding comes from the fact that DNA sequences vary widely from person to person. If you turn the restriction enzyme loose on a chromosome, you'll get a bunch of fragments that biologists call, with their usual indifference to language, restriction fragment length polymorphisms—RFLPs, or riflips. Riflip patterns differ from person to person because there are individual differences in DNA sequences. Use the restriction enzymes on chromosomes from a husband and wife, and you'll get two different riflip patterns.

The way you use riflips for genetic mapping is to study a big family afflicted with a genetic disease and find a specific riflip pattern that's present in family members who have the disease but not in the disease-free members. That grueling and expensive process has produced some notable successes: location of the genes for Huntington's disease—the malady that killed Woody Guthrie—for muscular dystrophy, and for cystic fibrosis, for example. But to do this kind of mapping you need not only the right family but also appropriate "markers," an identifiable physical location on a chromosome—a gene, a riflip, a restriction-enzyme cutting site. The dream of gene mappers is to have a regularly spaced set of markers at close intervals.

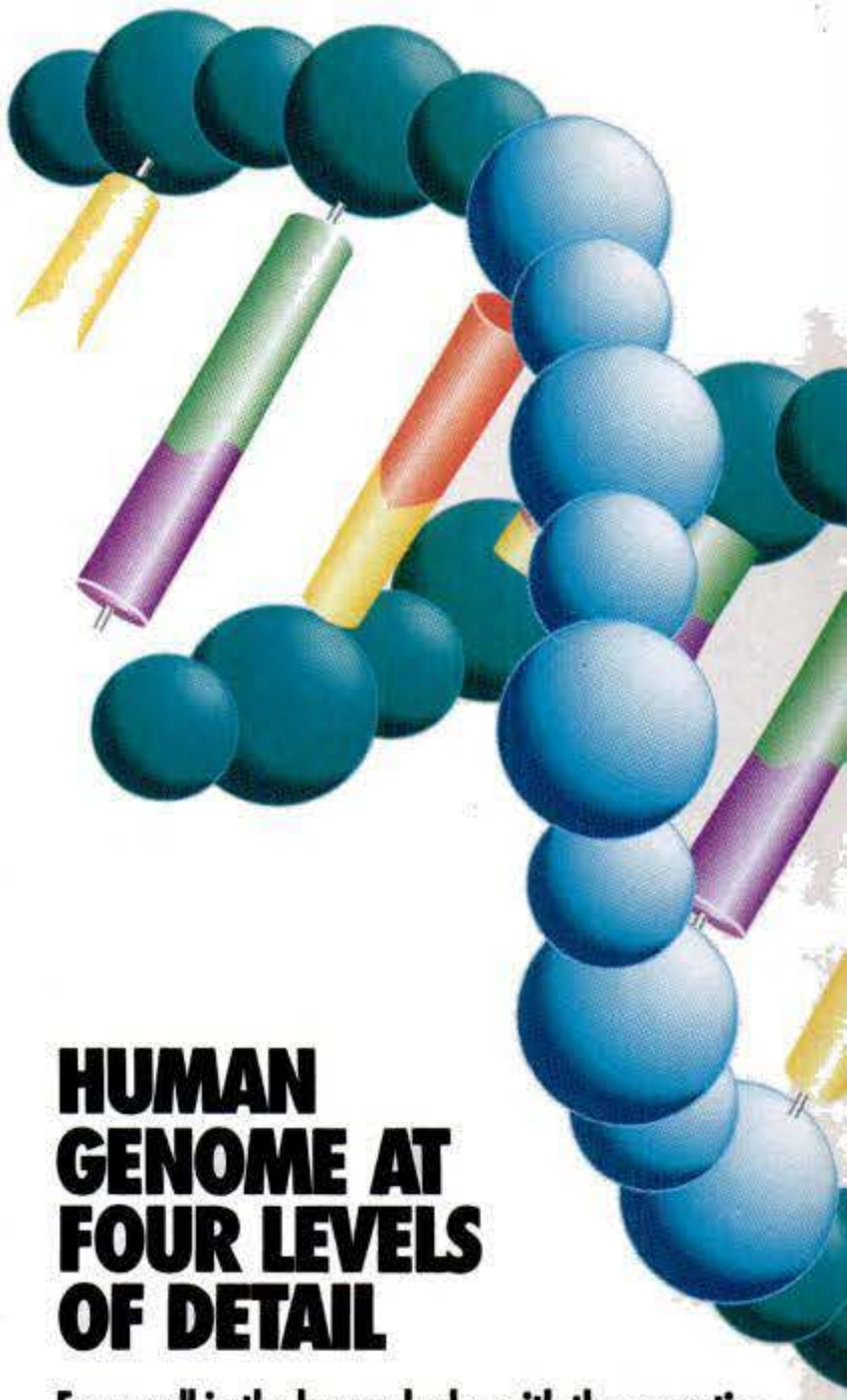
A physical map, by contrast, gives you the structure of the DNA itself. You make a physical map by chopping a chromosome into pieces and putting those pieces into an ordered sequence by identifying their overlapping ends. Physical maps come in various scales, depending on the size of the pieces.

A physical map consists of a number of fragments of DNA that have been cloned and put into a suitable living organism. The pieces are named contigs, because they are contiguous segments of DNA. One favorite place to store contigs is in cosmids, laboratory-modified viruses. A cosmid can hold a DNA fragment approximately 40,000 bases long. A newer storage site is the YAC, yeast artificial chromosome, developed by Maynard Olson at Washington University in St. Louis. A YAC holds 400,000 base segments, so an entire library of human contigs can be stored in approximately 60,000 yeast cells.

The ultimate physical map is the complete DNA sequence of all three billion bases in the human genome. That goal is furthest away. So far, less than one percent of the human genome has been sequenced, and the work is not advancing at breakneck speed.

Genetic map, physical map, sequence—these don't complete the list of the genome initiative's goals. As a kind of prelude to tackling the three billion bases of the human genome, geneticists are now trying to sequence the genomes of less complex creatures running to a mere several million bases each. Among them are the mouse, a yeast, a bacterium, the fruit fly and a roundworm, all well-established as laboratory models.

The organizational structure that's going to make all this possible is as complex as the project's goals. There is



## HUMAN GENOME AT FOUR LEVELS OF DETAIL

**Every cell in the human body, with the exception of the reproductive cells and mature red blood cells, contains 23 pairs of chromosomes, one set from each parent. Each chromosome is a dense and entwined package of DNA (deoxyribonucleic acid). The DNA molecule has the form of a double helix, composed of twin strands. Each strand is a huge polymer made of repeating nucleotide units, each consisting of a phosphate and a sugar (deoxyribose) group. The strands are joined at each nucleotide by a pair of connected bases. Because of the invariant distance between the strands—20 angstroms—and the molecular geometries involved, the connections can be only either guanine and cytosine (G and C) or thymine and adenine (T and A). There are some three billion base pairs in the human genome, and the enormous number of possible sequences is the secret of the vast information-carrying ability of the genetic code.**



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CELL

NUCLEUS

CHROMOSOMES

DNA

DNA DOUBLE HELIX

SINGLE NUCLEOTIDE

H (HYDROGEN)

C (CARBON)

O (OXYGEN)

PHOSPHATE

DEOXYRIBOSE (SUGAR)

GUANINE

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an Office of Human Genome Research in the National Institutes of Health, which is supposed to supply most of the money. There is a corresponding organization in the Department of Energy, which has carved out its own set of targets. There is a Human Genome Organization, HUGO, started to enlist international support and run separately from any government office (but led by many of the same people who are working on the U.S. efforts). Things could get even more complex as other nations join in.

One such country is the Soviet Union. Despite reservations over the cost of the project, the State Committee for Science and Technology approved a human genome research effort in 1989, one of fourteen scientific-technical programs to receive priority in the Soviet Union. It was organized by the Institute of Molecular Biology of the Academy of Sciences and was initially funded with 25 million rubles—about $4 million at the official rate of exchange.

Evans of the Salk Institute, whose laboratory was one of the first to get money in the initial round of genome funding, is pushing ahead with innovative ideas for physical mapping. For example, he's made a two-dimensional array of cosmids that enables a computer program to find neighboring contigs more easily than before.

"We've taken that idea to its logical extreme," he says. "We thought that instead of using a two-dimensional array, we could use a cube, a three-dimensional array, and see where the planes intersect. Then we said we could compress it even more by doing a set of cubes, which would be a hypercube. We've written an article called 'Genome Mapping in Multidimensional Spacing.' It turns out the limit is a five-dimensional array."

Physical mapping and genetic mapping can go together, Evans adds. He's using probes that detect DNA sequences known to be associated with genes to help find genes on contigs. He's come up with more than a dozen candidates that are being investigated.

Another bright young researcher, David Cox at the University of San Francisco, also has a new strategy for genetic mapping. He calls it radiation hybrid mapping: Put copies of a single chromosome in hamster cells, bombard them with X-rays to break up the chromosome, and then study the resulting fragments. "We use 8,000 rads of X-rays, and one of our map units is 50,000 base pairs," Cox explains. "That gets you in a range where you can actually clone the pieces of DNA." You can tell the closeness of two genes by seeing how often they are found on the same chromosome fragment.

Both Evans and Cox illustrate how the genome project is bringing together highly competitive geneticists. Cox has organized a concerted effort to map chromosome 21. The 30 or so major groups working on that chromosome have agreed to pool their data to develop a common set of landmarks for it. And Evans is one of six researchers who are getting a complete set of Olson's 60,000 YACs, developed at enormous effort. Both developments have biologists shaking their heads in delighted amazement because they break the tradition of never letting your neighbor know what you're doing until it's absolutely necessary.

An equally amazing development was an agreement reached in May 1990 by all the major gene mappers to pool their data for a definitive map, with 150 markers evenly and closely spaced across all the chromosomes. "Jim Watson and Maynard Olson deserve the Nobel Peace Prize for that," says one biologist familiar with the antagonisms and rivalries among gene mappers.

Another potential sore point, the participation of the Department of Energy, also seems to be yielding to the spirit of good will. With the same candor its predecessor agency brought to the atomic bomb, the DOE has parceled out three human chromosomes to three national laboratories: number 21 to Lawrence Berkeley in California, 19 to Lawrence Livermore in California, and 16 to Los Alamos in New Mexico. Bureaucratically, it makes sense. With the apparent end of the cold war, the DOE's national laboratories are looking for a new mission. But many scientists—including some in the genome project—aren't sure it will make scientific sense because the DOE doesn't have a great background in genetic research.

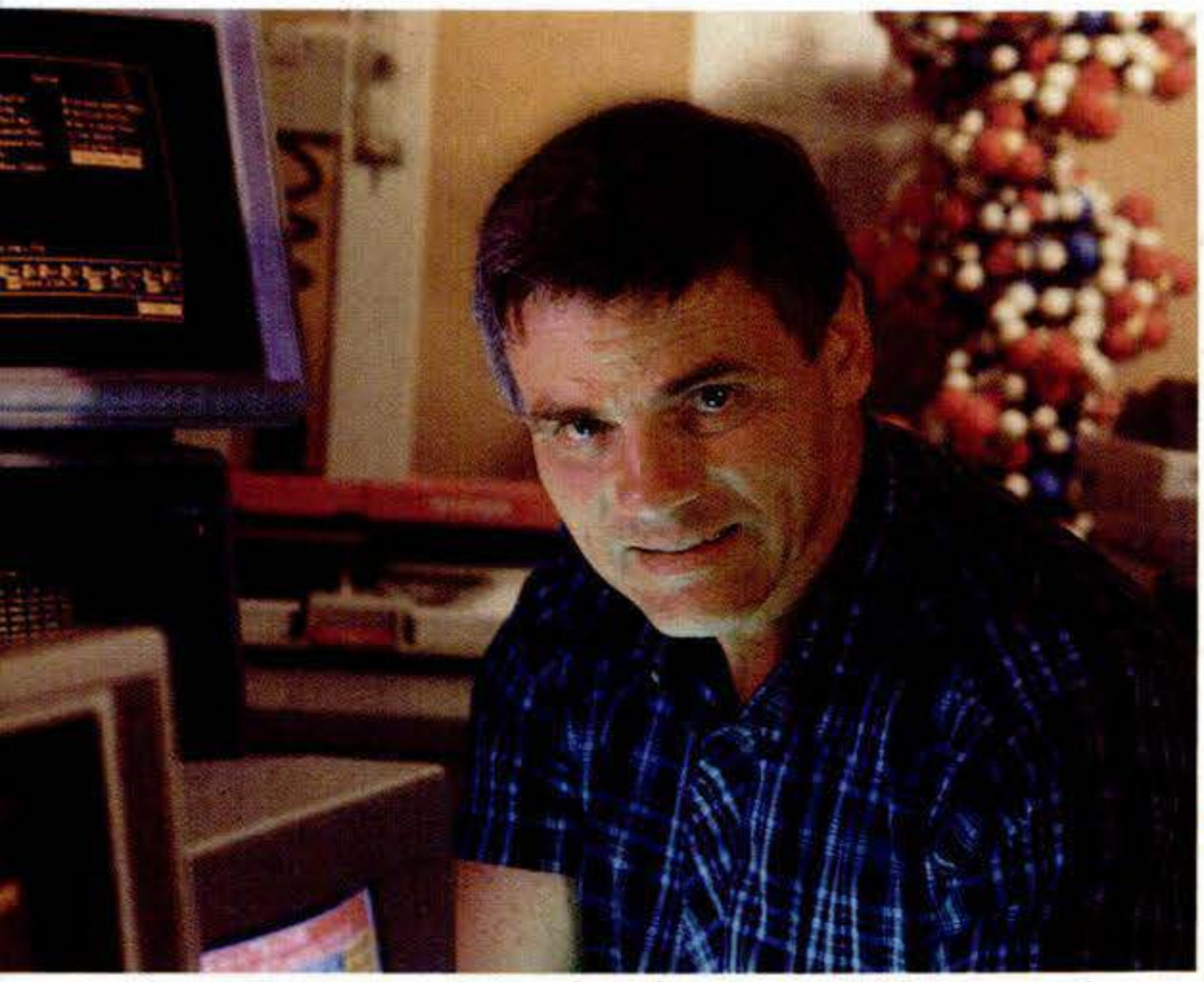
"We're very much in the setting-up stage," says Charles Cantor, a world-class geneticist who works at Lawrence Berkeley. Take physical mapping, he says. There's the bottom-up method, where you break a chromosome into a zillion pieces and try to put them in order; and there's the top-down method, where you break the chromosome into a few pieces, then break those into small pieces and put them in order before assembling the big pieces.

"What we're trying to set in motion is a couple of second-generation strategies," Cantor says. "In one we'll try to go from large fragments of DNA directly to clonable smaller pieces that are preassigned to the big pieces. We'll reduce the problem of making contigs to forty small problems rather than one gigantic one. The other approach we're using is to order and fingerprint not random fragments but two carefully chosen specific libraries that overlap just at their edges. Pilot studies are being done, and we'll be in large-scale implementation in six months."

But the all-out enthusiasm of most geneticists for the genome project isn't shared by many people outside their field. Theodore Friedmann, a physician at the University of California at San Diego who is working on gene therapy, says the genome project won't give him any immediate help. "For the time being, we need to solve the technical problems we have with existing models—how to insert genes into cells, how to ensure they are expressed stably without injuring the cell."

Arno Motulsky of the University of Washington in Seattle, one of the nation's leading figures in genetic medicine, was more positive—with one notable reservation. "The more we know, the more we can do testing that will help people," he says. "We wouldn't understand a thing about genetic disease if we didn't have the basic science behind it. The field is ready for the mapping of the human genome. But I'm not enthused over the sequencing of the genome."

Figuring out the complete sequence is the most controversial part of the project. One big reason is that most of the human genome consists of non-



PETER MENZEL

**Geneticist Leroy Hood uses robotic devices to assemble genes unit by unit.**



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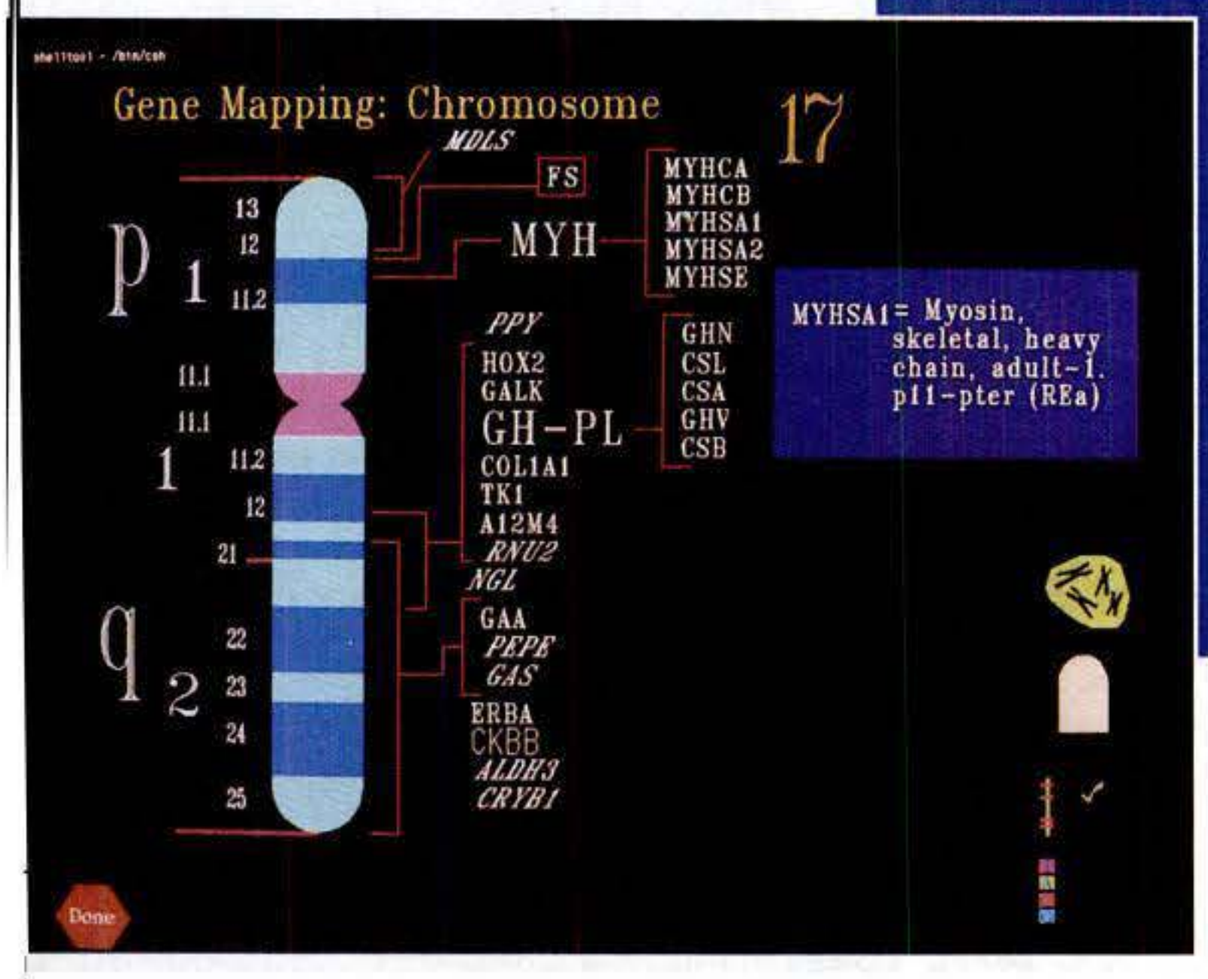
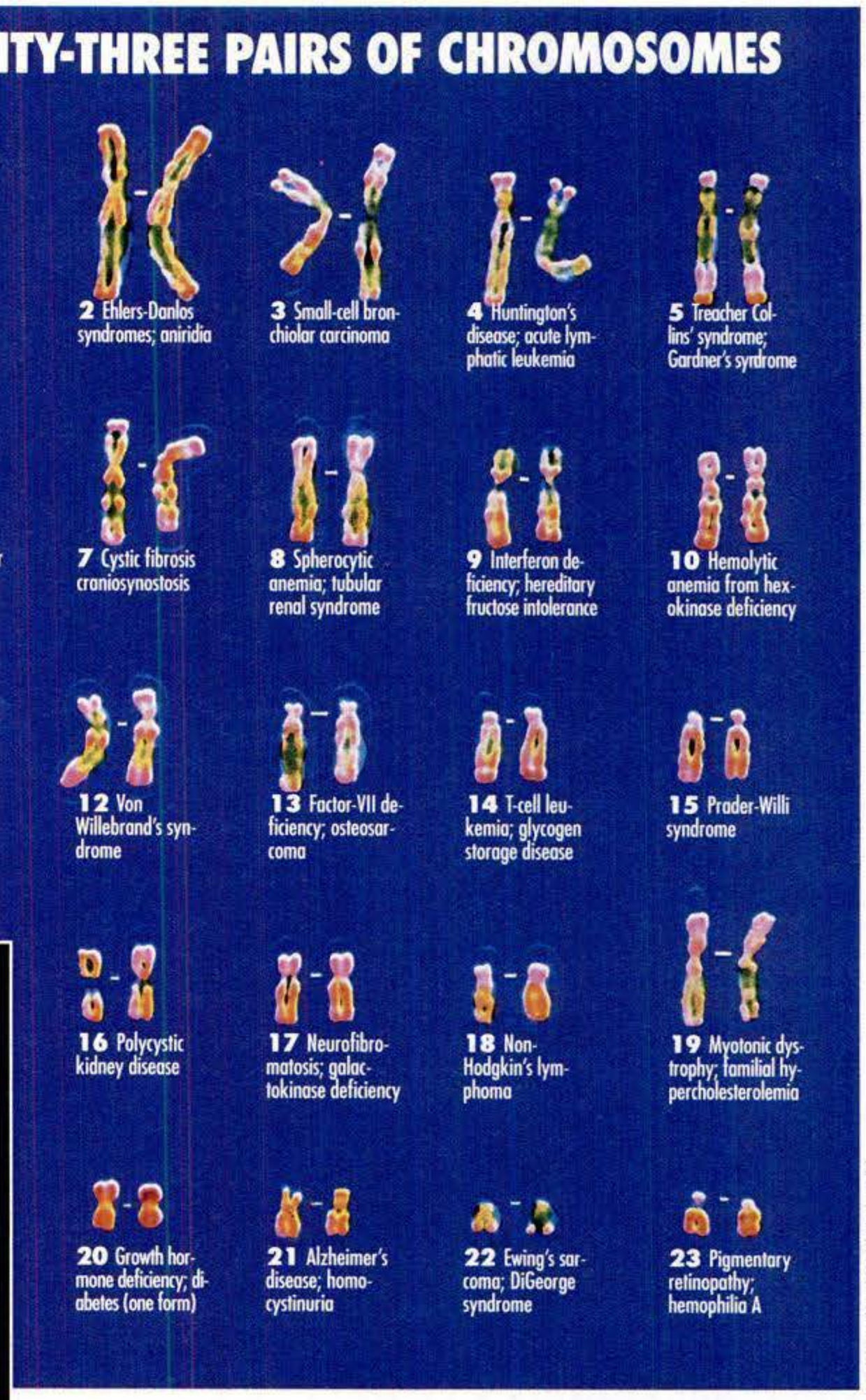
sense—long, repeating segments of DNA that don't seem to say anything at all. Only a small portion of the human genome, maybe two to five percent, encodes for genes. Many scientists don't see much sense in spending money to read those nonsense sequences. For example, Robert Weinberg of the Whitehead Institute in Cambridge, Mass., whose work with cancer genes is world class, is on record as opposing the exploration of what he calls "a vast sea of drivel" in human DNA.

The organizers of the genome initiative say they're not going to do that kind of exploring for a while—for economic reasons, they claim. Sequencing costs a lot. In Hood's lab, it costs $1 a base. In most other places, it costs closer to $10 a base. The official plan now is to delay mass-production sequencing until the cost is brought down 10- to 100-fold, to 10 cents a base or less. Scientists say that they will assess sequencing progress over the next five years before they decide on





TWENTY-THREE PAIRS OF CHROMOSOMES
1 Galactose epimerase deficiency; elliptocytic anemia
2 Ehlers-Danlos syndromes; aniridia
3 Small-cell bronchiolar carcinoma
4 Huntington's disease; acute lymphatic leukemia
5 Treacher Collins' syndrome; Gardner's syndrome
6 Hageman factor deficiency; spinal-cerebral ataxia
7 Cystic fibrosis craniosynostosis
8 Spherocytic anemia; tubular renal syndrome
9 Interferon deficiency; hereditary fructose intolerance
10 Hemolytic anemia from hexokinase deficiency
11 Manic depression; B-cell leukemia
12 Von Willebrand's syndrome
13 Factor-VII deficiency; osteosarcoma
14 T-cell leukemia; glycogen storage disease
15 Prader-Willi syndrome
16 Polycystic kidney disease
17 Neurofibromatosis; galactokinase deficiency
18 Non-Hodgkin's lymphoma
19 Myotonic dystrophy; familial hypercholesterolemia
20 Growth hormone deficiency; diabetes (one form)
21 Alzheimer's disease; homocystinuria
22 Ewing's sarcoma; DiGeorge syndrome
23 Pigmentary retinopathy; hemophilia A

CNRI/SCIENCE PHOTO LIBRARY

**Above: All 46 chromosomes of a normal woman are shown photographed in false color. The 23rd pair consists of two X chromosomes; a male has an X and a Y instead. Each pair is shown with some of the genetic defects associated with it. Left: A computer graphic gives an expanded view of diseases associated with chromosome 17 and the location of the genes responsible.**

an all-out assault on the sequence.

The leaders are convinced they'll get their total sequence sooner or later and that it will be worth it. "There may be reasons we don't know for keeping the extra DNA," says Zinder of Rockefeller University. "We can call ninety-five percent of it junk, but we have to think of it differently. Would it work better if the DNA encoding genes were shrunk down to one percent? Are there structural reasons for embedding DNA within DNA? We haven't the vaguest idea. Only when we have lots of it sequenced will we be able to figure out if there is a reason."

Doubts have also been expressed about the scientific value of the project. "In principle, their catalog would make my work easier," says Robert Tjian of the University of California at Berkeley, who works on the proteins that regulate gene expression. "My worry is it's going to be a long time before these guys get to the point where they're providing us with valuable information."

Economics looms behind much of the criticism. These are tough times in biological science, especially for the young researchers who are the hope of the field. Fewer and fewer are getting the first grants they need.

"American biological science is in jeopardy because of the current grant situation," Rechsteiner of the University of Utah says. "Diversions of any kind to a big project like this with little training for young scientists are unwarranted."

Zinder and other geneticists say the real money problems have other causes —the vast increase in spending on AIDS, for example—and that the genome project isn't taking funds from anyone because it's all new money. That argument doesn't impress Rechsteiner. "If you were going to add $200 million to the NIH budget, I would argue there are better ways to spend the money scientifically," he says.

Then there are the ethical worries about misuse of genetic knowledge. Friedmann recalls the turmoil that came with mass screening for the sickle cell gene among American blacks in the 1970s, when many sickle cell carriers unjustly experienced problems with employment and insurance because of the costs incurred by victims of sickle cell anemia. "With long-range health prognostication possible through

[*Continued on page 83*]



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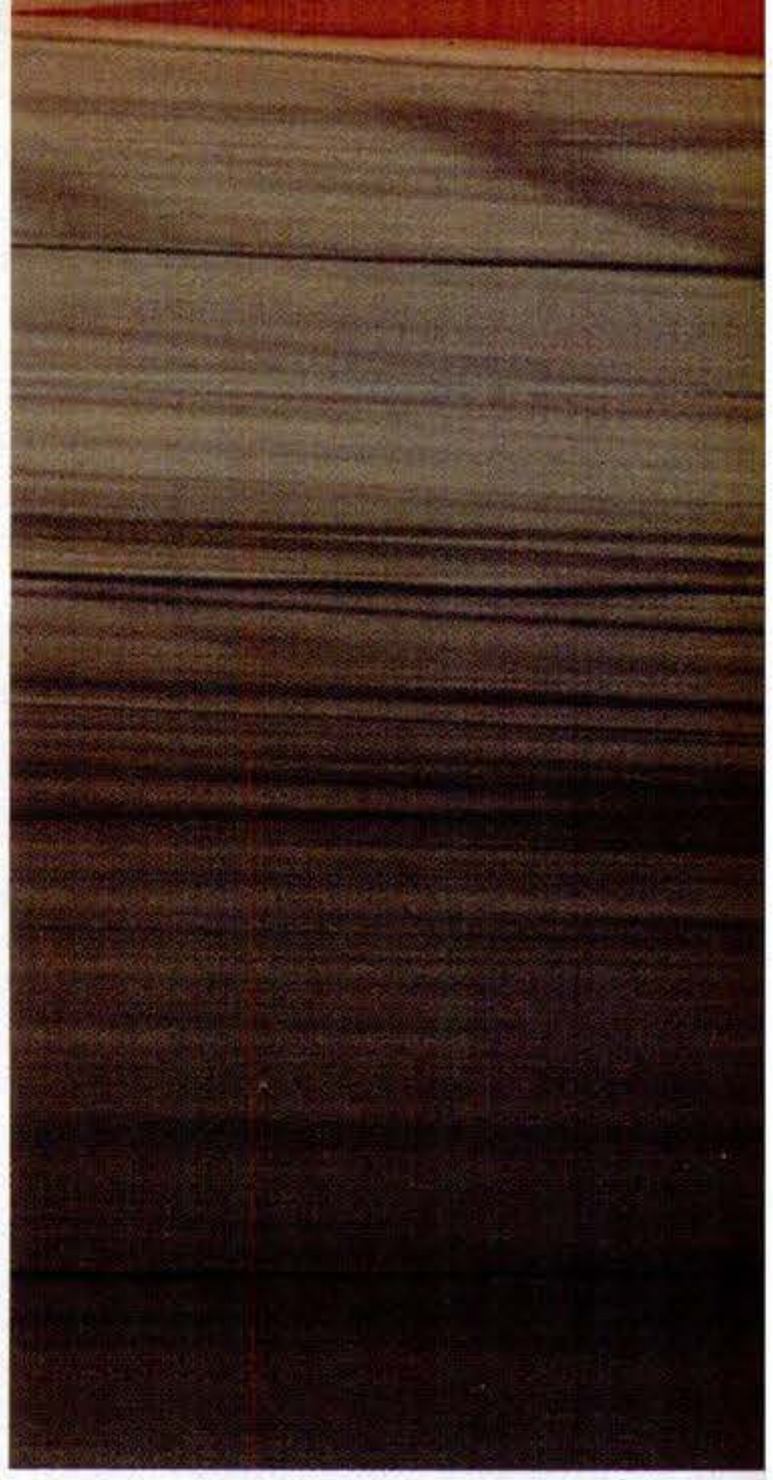
# ELECTRIC CAR SHOWDOWN IN PHOENIX

## ZINC-AIR BATTERY WINS



By RICK COOK

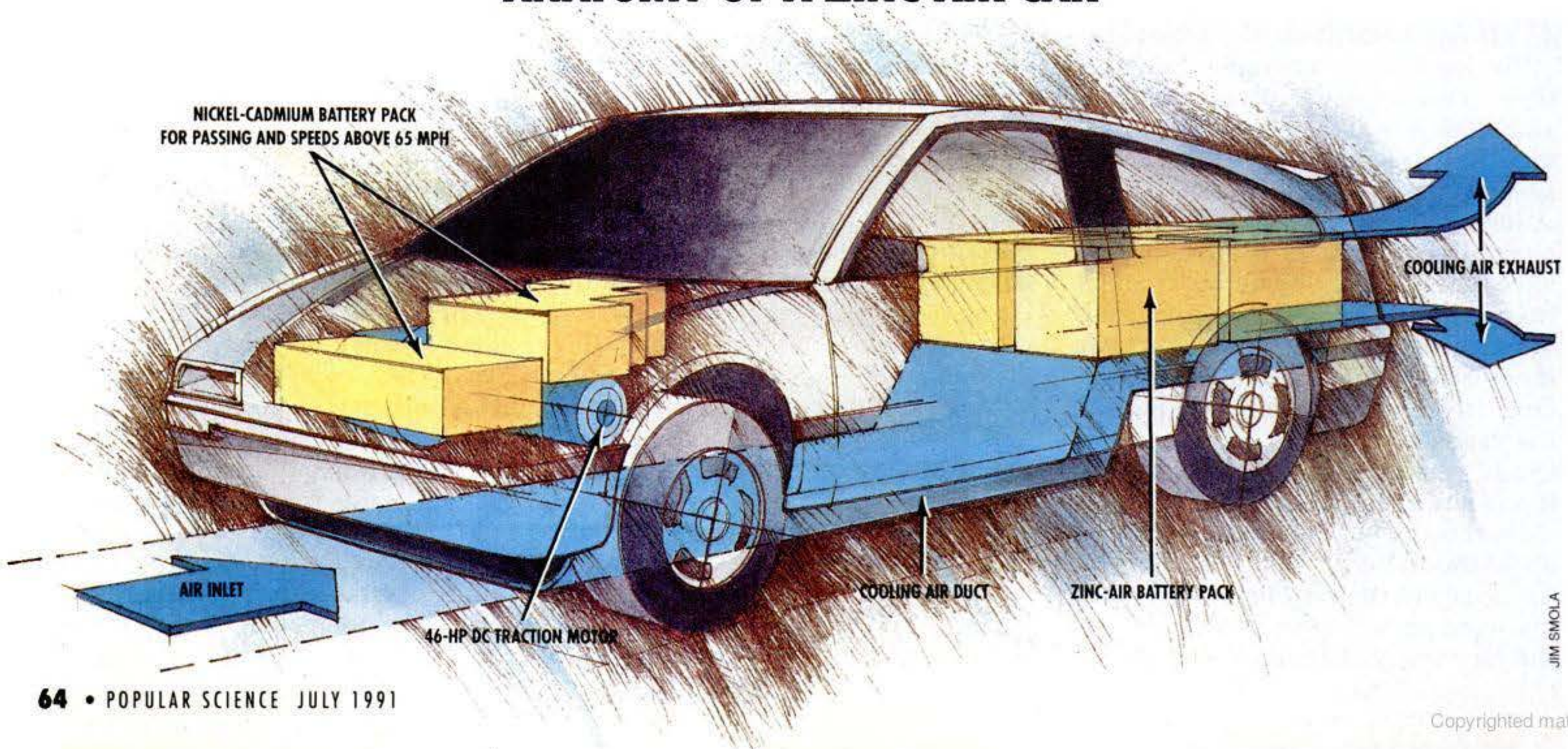
Zinc-air batteries got a sharp boost in the competition to power the coming generation of electric cars this April; a car running on the new batteries blew the doors off the rest of the field in an electric stock-car race. In the Electric 200, a 200-kilometer (124-mile) race at Phoenix International Raceway in Arizona, a modified Honda CRX coupe powered by zinc-air batteries breezed into first place, completing 108 laps in two hours and finishing four laps ahead of its nearest competitor.

The field neatly reflected the state of electric vehicle technology today: a wildly heterogeneous mix of hobbyists, entrepreneurs, and the occasional researcher. One electric vehicle hobbyist entered the converted Karmann Ghia he drives to work every day and cruised the track at 20 mph until he ran out of power. The crew of the Lead Sled, a full-size Navy-surplus station wagon, recharged the vehicle's bank of lead-acid batteries several times during the race. Solectria Corp., an Arlington, Mass., electric vehicle company, entered two of its production cars, one of which placed second.

Sponsored by Southern California Edison Co., Arizona Public Service Co., and battery-maker Dreisbach Electromotive, Inc. (DEMI), the winning car was put together in less than two months for $90,000. It was intended as a demonstrator for a new generation of zinc-air batteries.

Demonstrate it did. As other entries dropped out with dead batteries or made pit stops to recharge, the CRX cruised the track at 50 to 60 mph. (In an earlier qualifying run, the car averaged 69 mph.) DEMI research director Mike Cheiky estimated it could have gone about 15 mph faster if its electric motor hadn't overheated. At the end of the race, the zinc-air battery still had approximately one-third of its

## ANATOMY OF A ZINC-AIR CAR



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charge left—enough to go another 50 miles at the same speeds.

In the last three years, zinc-air cells have gone from being completely unsuitable for electric vehicles to being among the hottest battery prospects for practical electric cars. There is still a lot of work to be done, notably in improving battery life and power output, but zinc-air's backers are confident the goals can be met by the end of the decade.

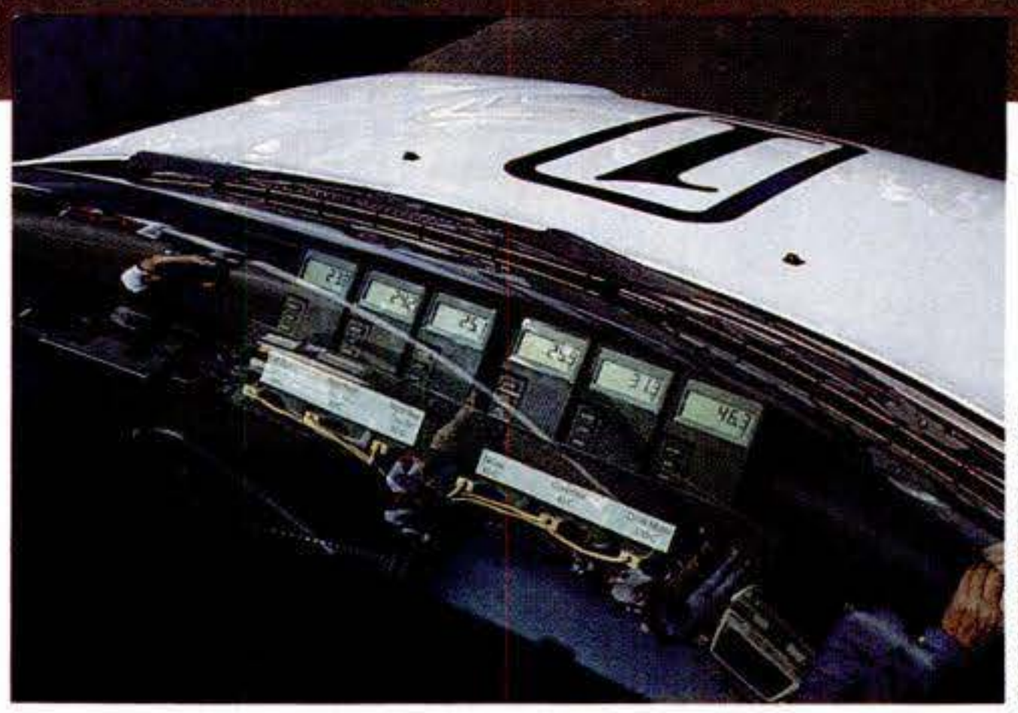
What makes the new zinc-air batteries a good bet for electric cars is their combination of reasonable cost and life expectancy plus high energy-storage capacity. Energy density, energy stored per kilogram, is critical for a practical electric car battery. Zinc-air batteries have one of the highest energy densities available.

Gasoline, which is superior to any existing battery, has an energy density equivalent to about 400 watt-hours per kilogram. A lead-acid battery holds roughly 25 watt-hours per kilogram, and an advanced sodium-sulfur battery can store about 100 watt-hours per kilogram. DEMI says that a zinc-air cell has a potential energy density of about 200 watt-hours per kilogram, and it has already observed energy densities of 160 watt-hours per kilogram in an electric vehicle driving on city streets.

The 750-pound zinc-air battery pack in the CRX holds 45 kilowatt-hours of electricity. By comparison, the four kilowatt-hours of nickel-cadmium batteries—needed for bursts of power—weighed 350 pounds. Zinc-air cells can be quick charged like lead-acid cells. A 12-minute flash charge can give the CRX enough energy to go about 40 miles at 30 mph. A one-hour charge gives it a 100-mile range. The battery pack can be completely replenished overnight.

One of the remarkable things about zinc-air batteries is how rapidly they're progressing. In a project that began two years ago, DEMI supplied Southern California Edision with a modified Chrysler minivan fitted with what were then state-of-the-art zinc-air batteries. Since that time, DEMI researchers have quadrupled the energy output of the van's batteries.

A zinc-air battery uses oxygen from the air absorbed into porous carbon as a cathode and zinc (usually a zinc alloy) as the anode. The electrolyte is a solution of a strong base, such as potassium hydroxide. Essentially the battery produces



PHOTOS BY KERRICK JAMES

**A HondaCRX laps the field at Phoenix International Raceway (top); an electric motor mated to the car's five-speed transmission gives a top speed of 87 mph. LCDs show the battery condition (above).**

electricity by converting zinc and oxygen into zinc oxide. When the battery is recharged, the zinc is reconstituted and oxygen is given off.

Zinc-air batteries aren't new. They have been used for years for hearing-aid batteries and to power signals at railroad switches. They have also been investigated by everyone from NASA to Sandia National Laboratories to Ford Motor Co. But while their energy density was well known, so were their problems. The two main ones were that zinc-air cells were not rechargeable and they could not supply high currents. There was a lot of energy in the battery, but it could only be drawn out in a trickle.

Fundamentally, this was a matter of design. On recharge, the zinc tended to grow treelike dendrites, which shorted the cells. Carbon dioxide ($CO_2$) in the air reacted with the electrolyte to form an insoluble carbonate. Evaporation or absorption of water from the air could vary the concentration of the electrolyte.

In the eight years since DEMI started working on the batteries, most of the problems have been overcome. According to Len Danczyk, director of market development at DEMI, the company has evolved "multiple defenses" against dendrite growth.

Although DEMI won't discuss details, Dr. Philip Ross, a senior scientist at Lawrence Berkeley Laboratory in Califor-

[*Continued on page 82*]



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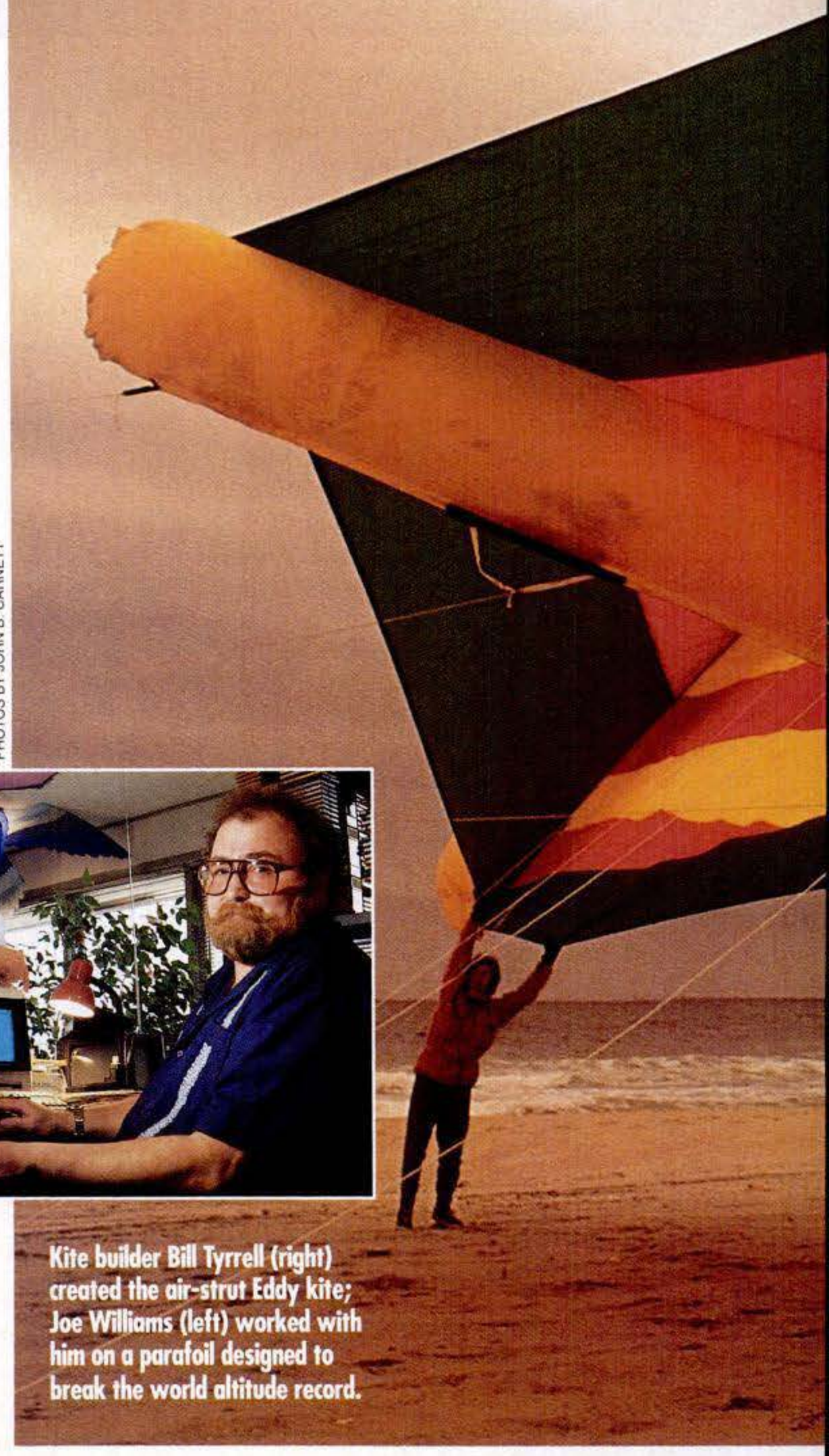
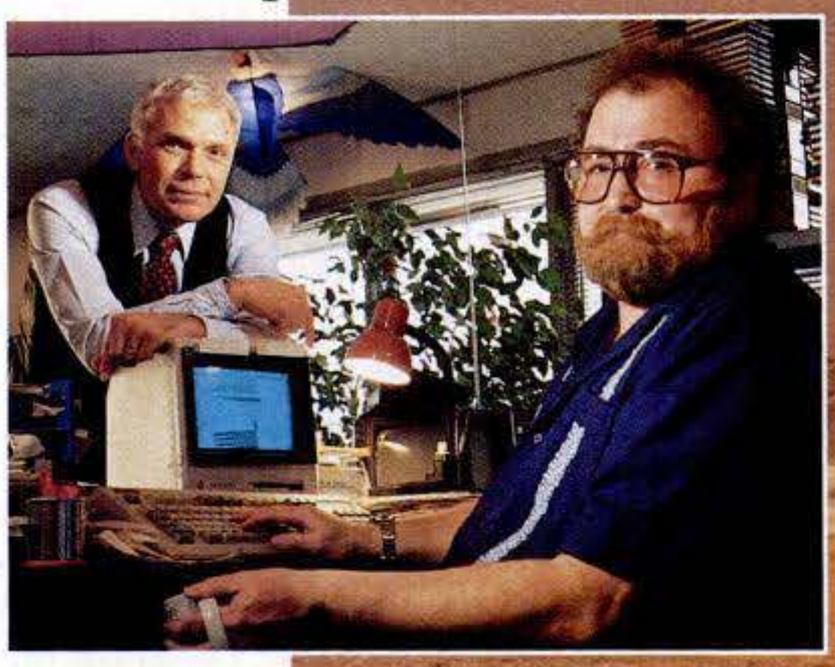
# THE SKY'S NO LIMIT

Kite builders are using the high-tech materials born of science to reinvent the kite. Next up: aiming to beat the world altitude record, now more than two miles high.



PHOTOS BY JOHN B. CARNETT



Kite builder Bill Tyrrell (right) created the air-strut Eddy kite; Joe Williams (left) worked with him on a parafoil designed to break the world altitude record.

**By MAXWELL EDEN**

Appealing equally to the mystic, scientist, do-it-yourselfer, and the child, the kite is one of those marvelous inventions that has served as an ongoing source of delight and scientific inspiration. Among other incarnations, the kite has been used to ward off evil, deliver love messages, raise banners, discover that lightning is electricity, drop propaganda leaflets, catch fish, spy on enemies, send radio signals, measure the weather, photograph Earth, and lift passengers into the sky.

Historical evidence indicates that the kite was popularized, if not invented, nearly 3,000 years ago in China, where materials ideal for kite building existed in great abundance—silk fabric for sail material, fine silk for flying line, and resilient bamboo for a strong, lightweight framework, the high-tech materials of that long ago era.



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## FLYING ON AIR

Large kites (other than the soft parafoil) present special problems in the framework department. The spars must be rigid enough to support a massive sail area, yet light enough to let the kite fly. This 50-foot-tall kite would normally require six-inch-diameter fiberglass struts weighing nearly 200 pounds—expensive, heavy, and dangerous to land. Kite builder Bill Tyrrell's 1,300-square-foot ripstop nylon giant Eddy flies in winds of less than 10 mph using inflatable spars that are pumped up to one pound per square inch of air pressure. The spars are rock-hard at a total weight of only 60 pounds; add another 25 pounds for the rest of the kite.


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Over the millennia, the kite can be traced eastward from the Orient to the West, where it eventually spawned the airplane. The Wright Brothers' flight in 1903 at Kill Devil Hills, N.C., was made in a kite-glider with a motor.

At the turn of the century, kite flying was a popular recreational activity. Kites carried meteorological measuring payloads miles up into the atmosphere and were indispensable experimental tools for the dawning science of aeronautics. After the airplane had become a reality, however, the kite mostly fell into the category of a mere child's toy.

The kite is not a fad, though. It continues to reinvent itself for each new generation to discover. Today, kites can fly in precise formations across the sky or stand still, while others are being designed to set a new world altitude record.

Economics bear witness to the kite's resurrection as an adult sport. Hundreds of kite shops around the country sell sophisticated and spectacular kites—many costing $100 and up—certainly not child's play. In addition, kite festivals and stunt kite competitions, both here and abroad, attract increasingly large numbers of enthusiasts.

Building and flying kites demand skill, ingenuity, and attention. In the hands of the kite builder, the high-tech materials born of science make possible a new, evolving breed of kites created to once again delight and inspire. PS

**Maxwell Eden is the author of *Kiteworks—Explorations in Kite Building & Flying* (New York: Sterling, 1989)**

## WHAT'S IN A KITE

Synthetics developed during the last 50 years provide the greatest improvements in kiting. The wide array of lightweight, durable, and accessible kite-building materials offers kite builders the opportunity to construct a rich variety of forms.

Ripstop nylon is, perhaps, the best all-around kite-sail material. With low weight, high tear strength, and almost no porosity, ripstop was originally developed as an inexpensive synthetic replacement for silk in the production of parachutes during World War II. The term "ripstop" was coined from the way the fabric is woven. Within the tight nylon weave, a larger diameter thread runs crisscross, forming a checkerboard of small squares. This interwoven grid gives the material rip-stopping properties. Should the fabric be punctured, the hole will not spread but remain contained within the interlocking network of small squares. Available in various weights, 0.75-ounce-per-square-yard-grade ripstop is the most popular among kite builders.

Other sail materials include such synthetics as high-count taffeta (nylon); polyethylene (trash-bag plastic); Tyvek (spun-bonded olefin), a highly tear resistant, waterproof paperlike material often used for envelopes by overnight delivery services; and Aeroform 0.55 WK by Orcon (a scrim of Kevlar aramid fiber and polyester on Mylar film), the strongest and lightest sailcloth available.

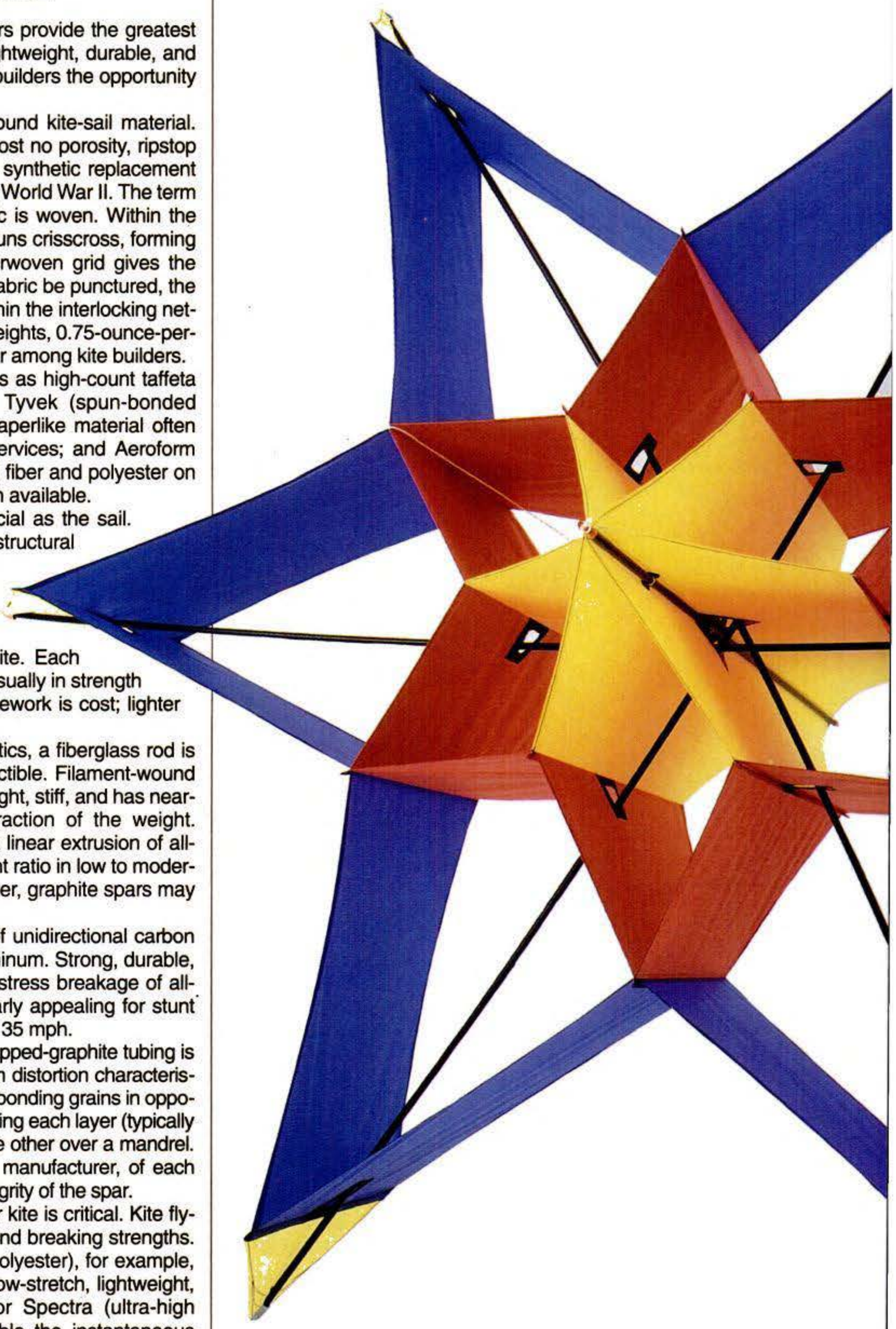
Spars for the kite's framework are as crucial as the sail. The low-to-high-wind-range capability and structural integrity of today's kites are due primarily to frameworks fashioned from rods of solid fiberglass or spar tubing materials such as filament-wound epoxy, all-carbon (graphite), aluminum carbon, and wrapped graphite. Each spar choice is a trade-off in some respect—usually in strength versus weight. Another factor in a spar framework is cost; lighter and stiffer mean more expensive.

Although it weighs more than other synthetics, a fiberglass rod is uniformly stiff, straight, and virtually indestructible. Filament-wound epoxy tubing (a fiberglass-epoxy mixture) is light, stiff, and has nearly the durability of solid fiberglass at a fraction of the weight. Stronger and lighter than fiberglass tubing, a linear extrusion of all-carbon tubing offers a good strength-to-weight ratio in low to moderately strong winds. Under high stress, however, graphite spars may suffer fatigue and eventual breakage.

Aluminum carbon shafts are constructed of unidirectional carbon fibers bonded to a core of high-strength aluminum. Strong, durable, and less prone to the structural fatigue and stress breakage of all-graphite spars, aluminum carbon is particularly appealing for stunt kites that perform in a wind range from 1.5 to 35 mph.

Stiff, strong, and remarkably lightweight, wrapped-graphite tubing is an aerospace-quality composite with minimum distortion characteristics. As a plywood laminate builds strength by bonding grains in opposition, wrapped graphite is fabricated by wrapping each layer (typically four wraps) in a crisscross angle pattern to the other over a mandrel. The angle, or degree, which varies with the manufacturer, of each wrap over the other is critical to the overall integrity of the spar.

Choosing the right flying line for a particular kite is critical. Kite flying line is now available in different lengths and breaking strengths. Strong, abrasion-resistant braided Dacron (polyester), for example, is acceptable for general single-line flying. Low-stretch, lightweight, high-performance fibers such as Kevlar or Spectra (ultra-high molecular-weight polyethylene) make possible the instantaneous response needed to control stunt kites.—*M. E.*





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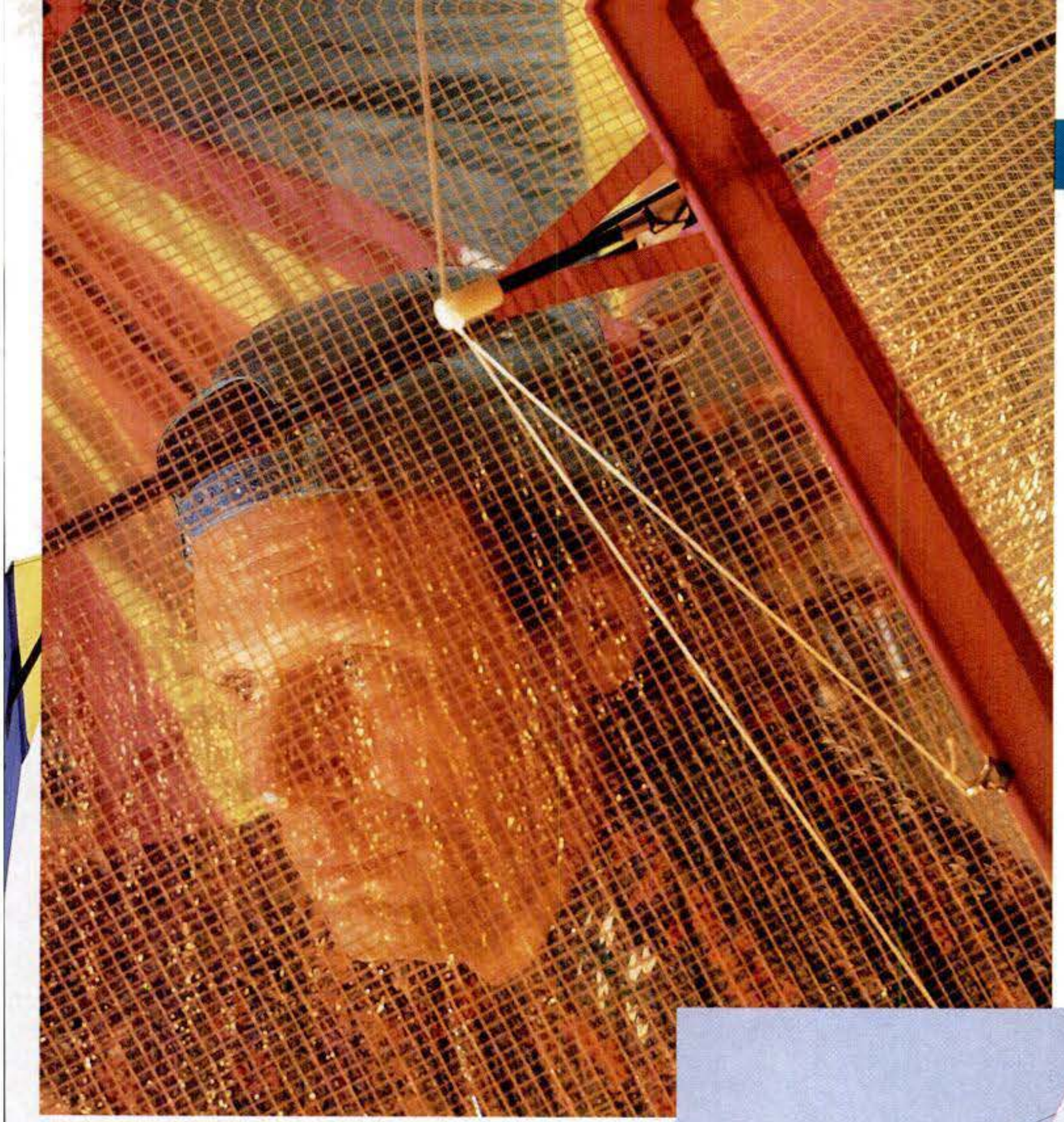
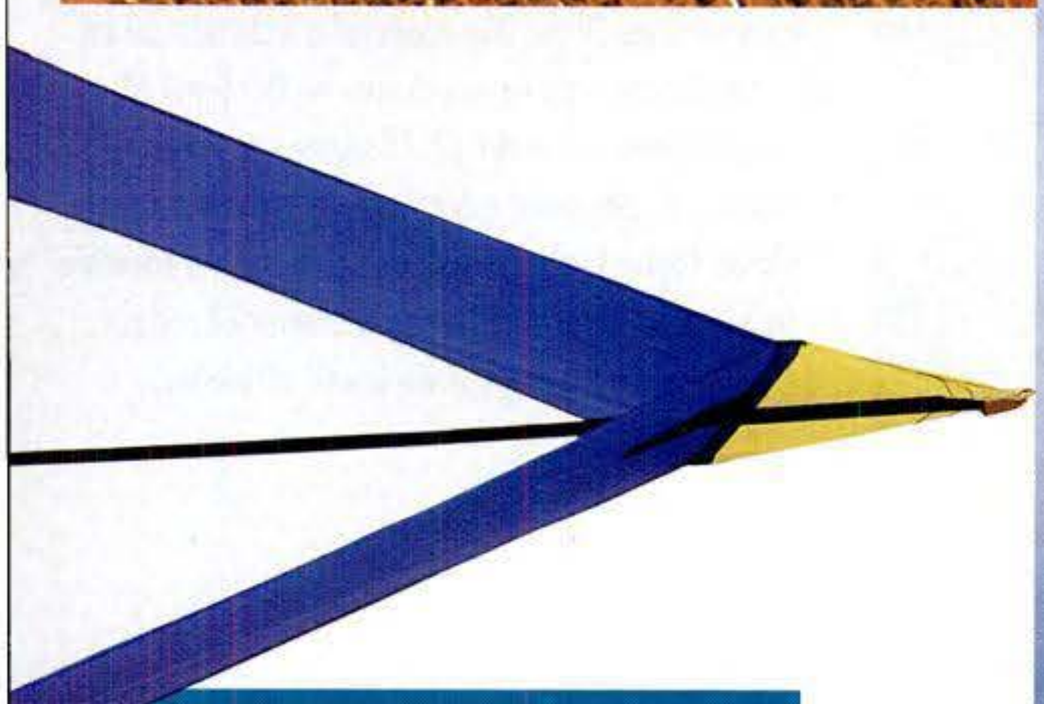


## AIMING HIGH

Designed to beat the existing single-kite world altitude record (12,471 feet, set in 1898), this brilliantly conceived and crafted six-foot-square winged box weighs only 26 ounces. The creation of Long Island-based kite designer Bobby Stanfield, the Celestial Navigator (shown in detail at left and in photo below, second from bottom) flies in an amazing wind range of 0.5 to 30 mph. Plans call for a payload consisting of an on-board altimeter to verify altitude and a camera to record the aerial voyage. A critical consideration in kite design is the minimum wind necessary to lift it. This ratio is called sail loading, and it is measured in ounces per square foot. The ratio is derived by dividing the kite's effective lifting area in square feet by its weight in ounces. A kite that will fly well in relation to its size conforms to an acceptable sail loading ratio of one ounce per square foot. Sporting a sail-loading ratio of a gossamer 0.33 ounces per square foot, the Navigator weighs nearly two-thirds less than the average kite. The impressive sail loading and open architecture of the kite are possible because of a revolutionary sailcloth and an innovative rigging system that tensions the sail to the graphite-tubing framework. At 0.70 ounces per square yard, Orcon Aeroform 0.55 WK (a 0.25-mil Mylar film reinforced with a Kevlar aramid fiber and Dacron scrim) is the lightest and most efficient sailcloth available. To maintain a taut sail evenly stressed throughout the kite's structure, the Navigator's spreader spars fit tightly into nylon rod caps connected to tension lines made of 100-pound test Dacron; these retaining cap fittings extend beyond the framework perimeter, maintaining the kite's structural integrity in the same fashion a suspension bridge stays up.



## STARFLAKE

A facet-type, high-aspect-ratio box kite variation of ripstop nylon with a kinetic capacity, the crystalline Starflake, when given line slack, tumbles and dives in long, controlled sweeps. Its multiple airflow cells are large enough to promote great lift while reducing drag at higher wind speeds. The asymmetrical keel is not only aesthetically pleasing, it also provides the kite with a self-correcting, or "righting," moment for pulling out of potentially disastrous dives. Catenary cuts on all wing sections maintain tension while creating a more efficient lifting surface and less drag; the kite is a stable, high-angle flier that climbs quickly even in gentle breezes. Three filament-wound epoxy-tubing cross spars set perpendicular to a center spine provide a rigid yet flexible tensioning system for a drum-tight sail. The Starflake was designed by Kathy Goodwind and Tom Mallard.

The compound Pro Spirit (bottom) is another creation of Stanfield's. The design marries two generic kite forms: the box and the delta. A box (stable in steady winds) combined with aspects of a delta (good low-wind performer) produces an aerodynamically superior hybrid, or compound, kite—a stable, high-angle flier that is light enough to rise on thermals. With a wrapped-graphite-tubing framework, this 64-ounce kite flies in an effective wind range of 1 to 25 mph.



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## SHOOTING FOR 15,000 FEET

**A different approach to the single-kite world altitude challenge is this computer-designed parafoil. Kite builder Bill Tyrrell's computer program integrated requirements such as airfoil shape (chord), lift, drag, material weight of the kite, and the weight and drag of the flying line. Considered the workhorse of kites, parafoils develop more lift than any other design. About half the weight of a recreational parafoil of the same dimensions, this 33-square-foot (80 inches wide and 60 inches long) prototype is made of Orcon Aeroform, weighs a scant 0.4 ounces per square foot, and flies in a wind range of 2 to 30 mph (with upper limits yet to be tested). The kite is lightweight yet strong enough to lift from 30,000 to 40,000 feet of thin Kevlar aramid fiber line to reach a projected altitude of 15,000 feet. The keels are designed with catenary cuts (front and back) to keep them taut, further increasing stability. Cross-port vents on the internal ribs maintain equal internal pressure, keeping the soft kite from collapsing in turbulence or crushing in crosswinds. Another version uses an Orcon film made of a light aluminum deposit measured in angstroms on 0.25-mil Mylar with a polyester scrim (0.75 ounces per square yard). The potential advantage of reinforced metalized Mylar is that it will be sufficiently reflective to make altitude verification a matter of radar tracking, eliminating the on-board altimeter.**

# HOW DOES A KITE FLY?

A kite is a heavier-than-air flying aircraft that must conform to the laws of aerodynamics. It requires a framework fitted with a sail. The exception is the soft airplane-wing-shaped parafoil, which has no rigid members and assumes its shape entirely from the wind. When tethered and fixed in a position to gain lift from the wind, a kite maintains a perpetual stall—poor aerodynamic design for an airplane but essential for a high-flying kite—moving neither forward nor backward, seemingly indifferent to gravity.

Kite flight is controlled by three main forces: lift, gravity, and drag. A kite flies because the lifting force of the wind overcomes both the downward pull of gravity and air resistance to the forward motion of the kite called drag. Lift is explained by the following:

1. Newton's third law of motion: To every action there is an equal and opposite reaction. Try this simple experiment to experience the aerodynamic forces at work on a kite fixed in the sky. With your hand outside the window of a moving car, keep your palm horizontal and fingers pointed directly into the wind. This position represents a low angle of attack with minimum lift and drag. Elevate your palm slightly above the horizontal, and the deflected wind lifts your hand upward. Increasing the angle of the palm induces turbulence and additional drag, limiting lift as the hand falls back in a nearly vertical position toward the horizon.

2. Bernoulli's principle: The pressure of a moving gas decreases as its velocity increases. This law of aerodynamics laid the groundwork for manned flight by anticipating the efficiency of a cambered wing, which explains why airplanes get off the ground, sailboats sail, and some kite forms fly. A cambered airplane wing is an efficient airfoil because the airflow is forced to move faster and farther over the top of its curved upper surface (causing lift) than across the flat bottom section of the wing.

3. Updrafts are created by the wind rushing upward along the edges of mountains and cliffs. Thermals are rising bubbles of hot air, often spanning miles, frequently found over large flat areas on hot days. Hang gliders, sailplanes, soaring birds, and kites can float high overhead for hours by taking advantage of these naturally occurring forms of air support.

Kites fly at an inefficient high angle of attack in a permanent stall. Once again the exception to the rule is the parafoil, which was modeled after an airplane wing. The parafoil's efficient low angle of attack (more nearly horizontal into the wind, like an airplane) owes its remarkable lifting ability to Bernoulli's principle.

Most kites, however, are pushed (Newton's third law of motion) more than they are pulled upward (as the hand-out-the-car-window example demonstrated), with other aerodynamic conditions contributing marginally to lift.—*M. E.*

**KITE SOURCES** *Kite building supplies:* High Fly Kite Co., Box 2146, Haddonfield NJ 08033; The Kitestuff Co., 51 Layle Lane, Doylestown PA 18901. *Kites by mail:* Color the Sky, 221 Yoho Dr., Anoka MN 55303; Flying Colors, 815 Spruce St., Boulder CO 80302; The Gasworks Park Kite Shop, 3333 Wallingford N., Seattle WA 98103; Into the Wind, 1408 Pearl St., Boulder CO 80302; Revolution Kites, 3089-C Clairemont Dr., Suite 171, San Diego CA 92117



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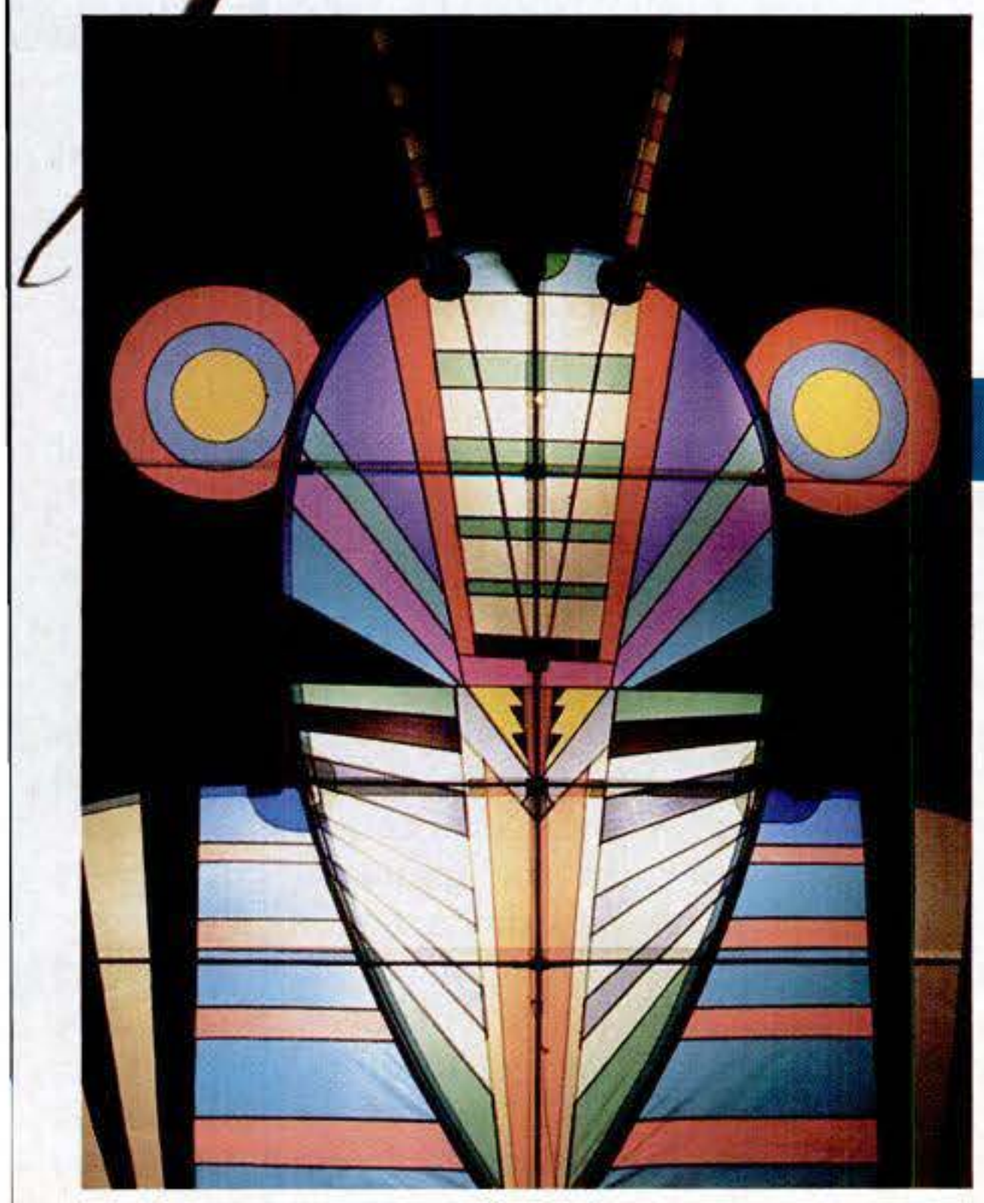
## COMPOUND KITE

**A combination of three kite forms—delta, sled, and parafoil—the Genesis 17-foot-wide-by-40-foot-long step-wing delta generates great lift without sacrificing stability. Built by Adrian Conn, of Windsor, Ont., the kite flies well in a wind range from 8 to 15 mph. A parafoil along the leading edge keeps the nose up and prevents stalling, while the multi-wing arrangement stabilizes the kite.**

## STATE-OF-THE-ART STUNT KITE

**A radical departure from the delta wing profile and conventional kiting theory, the high-aspect-ratio (nine-foot wingspan and three-foot chord) Revolution I, designed by Joe Hadzicki of Revolution Kites in San Diego, has two independently controlled aileron wings. Increasing or decreasing the lift on each wing using a quad-line control line system allows for instantaneous stopping, precise speed control in both forward and reverse flight, midair hovering in any orientation, and propellerlike spins. Because the Revolution's large wingspan requires a certain degree of stiffness to keep the wings from flapping uncontrollably, the ripstop sail is fitted onto light, yet extremely rigid, wrapped-graphite tubing. A distinctive twin triangular configuration makes for a strong, highly responsive, and stable kite. Subtle manipulation of the wing surfaces is possible because of Spectra flying line, a slippery, exceptionally low-stretch, small-diameter fiber that transmits instantaneous control movements from four control lines.**



## MANTIS MAN

**George Peters' anthropomorphic kite (left) is constructed of artfully pieced ripstop with a framework of fiberglass tubing and rod. Bridled from the head, the nearly 7-foot-wide-by-40-foot-long kite combines banners (parallel tail) and pennants (fully tapered tail) for additional stability and skims across the air like a raft across water. The long tail induces sufficient drag to stabilize the kite in one direction, as a rudder would for an aimless, free-floating raft.**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# AIR TRAFFIC TRAINING GETS REAL

LOGICON, INC.

**A super-sophisticated, super-realistic new simulator moves the training of air traffic controllers out of the Stone Age.**

**By JIM SCHEFTER**

You're the only controller in the airport tower, eighteen stories above the tarmac. A fuel truck scurries below, and a taxiing Delta DC-9 disappears behind the terminal to your left. An American 727 and a corporate Lear 25 wait for the active as a DC-10 lumbers on long final toward the ground. A voice crackles in your mini-headset, then another.

"Academy tower, United 67 Heavy on final..."

"...Tower, United 433 Heavy at Woody...landing..."

The only other person in the tower sits mute at his console behind you. The pressure is building. You do what you have to do. It comes out in a rush of words.

"United 67 Heavy cleared to land....United 344 continue inbound runway two-eight right."

"United 67 Heavy."

"This is United 433. Say again, please."

"Uh, roger....United 67, turn right first taxiway, contact ground control one two zero point two...Say again, United. What's your number?"

"Academy tower, United 43 Heavy..."

Suddenly it's too much. You cast about wildly for help. But the guy behind you is stone faced. This mess is yours, and you're in it alone. More alone than you ever thought possible.

You're in the middle of an airport that doesn't exist, except as a perfectly blended set of transparencies projected onto the inside curves of a spherical screen. That truck rolling past and the aircraft on the ground and in the air are high-resolution computer-video



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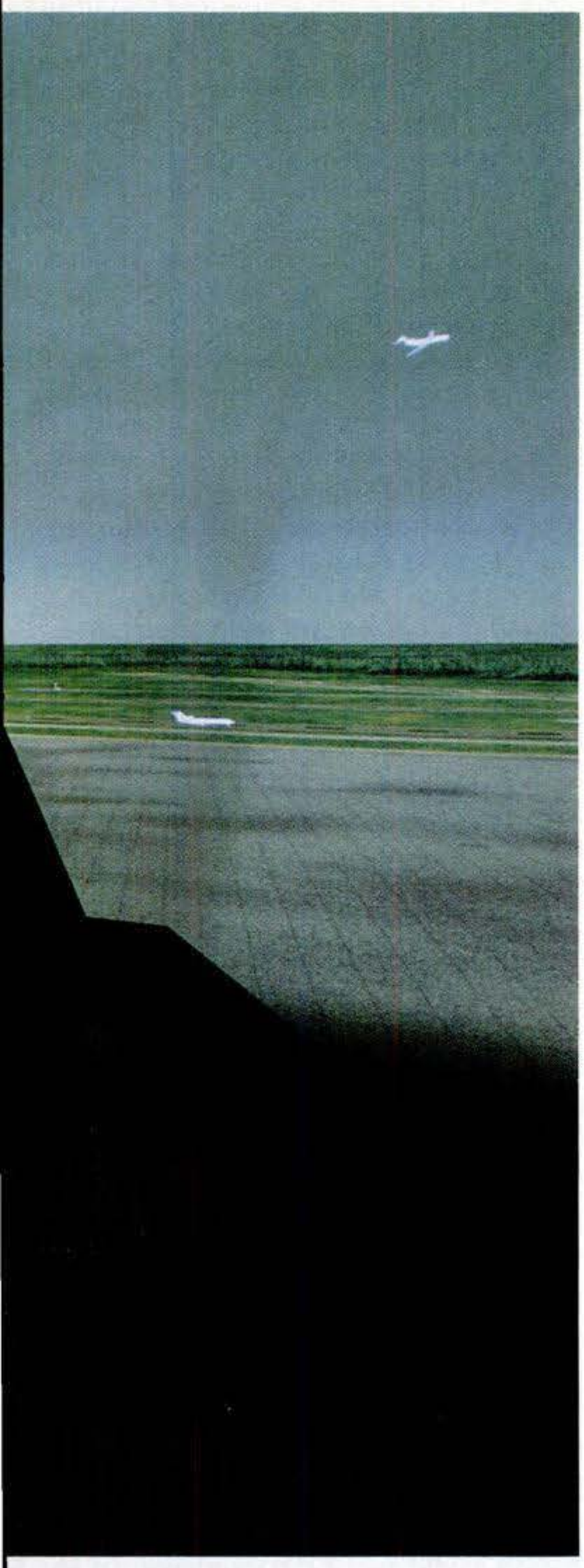

projections, so clean and detailed that you can look at them through binoculars without seeing pixels (picture elements), blurs, or jaggies.

Your console and the hardware around you are real enough, duplicating the equipment in an FAA control tower down to the radios, radar screens, weather instruments, and light gun. But the voices in your headset are stored in a machine. You're talking to a pseudopilot, a computer programmed for state-of-the-art voice recognition. And it's talking back.

You've messed up this session, and in another 10 seconds, you're not going to be alone anymore. The watching instructor is going to be in your face. He's human.

The almost-real world you've just exited makes Disney rides and the best arcade games look raw and unsophisticated. This is the Tower Operator Training System (TOTS), so advanced in visual projection and in computer voice recognition and response that it's all-but-indistinguishable from the real thing. Student controllers began training on the simulator this spring at the Federal Aviation Administration Academy in Oklahoma City. Another TOTS unit, set up for naval aircraft, will soon be operational at the U.S. Navy's training school in Millington, Tenn.

TOTS goes a world beyond the academy's existing training devices. Until now, students got all their simulated experience by directing model aircraft around table-top airports reminiscent of those old World War II battle layouts. They still start out that way. Students "control" model airplanes being manually pushed about on the table or being flown in for landings in the hands of other students, who sometimes even make engine noises. "Brrrr..rrr...rrr..."

"The tables serve a good function by introducing students to a tower environment," says the academy's Bob Hoppers, "but they don't go far enough."

Hardly. The tables and model airplanes used to be as close as student controllers got to an airport tower until they graduated, were assigned to one somewhere, and learned their real-world skills on the job. But today's students quickly move from tables to TOTS. The new trainer won't turn out more controllers, but it will turn out better ones.

"The FAA is adding badly needed realism to controller training," says John Galipault of the Aviation Safety Institute in Worthington, Ohio. "They'll be able to visualize spatial relationships, handle multiple aircraft, have emergency situations introduced, a whole host of new opportunities to learn. It's an important innovation."

Getting there wasn't easy in an age of tight budgets. The FAA hadn't convinced Congress that it needed such an advanced simulator until the U.S. Navy made the case for its TOTS system. "We piggybacked off the military development," Hoppers says, "and it's going to drastically improve the product we're sending out to the field."

The new tower trainer was designed and built by Logicon, Inc., at its Tactical and Training Systems division in San Diego. The company develops complex military software, computerized war games, and simulators. Each TOTS unit has two identical and independent tower cabs, or control rooms, supported by seven Sun Microsystems computers. Three student stations and an instructor's console in each cab look out over an airport scene projected onto a curved screen 23 feet high.

One of the simulator's goals is to let students feel the tension in their guts and the bile rising in their throats when things get just a little hairy. Thel Hooks, Logicon's program manager, tells what happened shortly after full-scale testing on TOTS began in San Diego:

"We had a batch of FAA guys out from Oklahoma City, and there was a situation where two planes were getting too close together. Their eyes got big, and they were reacting like it was real. I finally said, 'Hey, guys, relax. It's just a simulation.'"

It took more than three years of technical development and $10 million to achieve that degree of realism.

In addition to incorporating tower hardware into the trainer's cab, Logicon's experts had to pursue parallel efforts in both computer-generated graphics and voice technology.

Robert Gullen, with twin degrees in electrical engineering and fine arts, was able to use both his specialties as lead visual systems engineer for TOTS. "There are 150 million pixels in the background scene," he explains, sweeping his arm in the direction of a screen that curves overhead and through a horizontal arc of 210 degrees.

Six projectors beam a generic airport scene onto the screen, complete with apron and runways, taxiways, a terminal building, two general aviation hangars housing fixed-based operators, and miscellaneous support buildings. There's grass between concrete strips, complete with bald spots, trees in the distance, and even radio towers. Approach, runway, and taxiway lights are fiber-optic strands inserted precisely through the screen. Seen from inside the tower cab, the perspectives and details are completely lifelike.

**The FAA's new Tower Operator Training System (TOTS), with its lifelike views of a simulated airfield (left), supplements but does not replace the table-top method (above), in which trainees "land" and maneuver hand-held model airplanes.**

"The sky is mostly 'fill' light above ten degrees up from the horizon,"



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Gullen says, "so all those pixels are devoted to the landscape."

Artists at Angel Studios of San Diego "painted" the airport in high-resolution detail on a computer screen. The completed image was digitized and recorded in six overlapping frames on Kodachrome 64 film. "The details in the transparencies are right at the resolution limit of the film," Gullen says. "Each frame is 5,000 pixels square and perfectly color balanced."

Angel artists prepared the scene in 10 versions. Nine of them are daylight or dusk scenes with varying weather conditions, and the tenth is a night scene.

Up to 10 moving targets—a wide variety of commercial and private aircraft, including helicopters and airport ground vehicles—can be simultaneously superimposed on the background scene by computer-driven video projectors. Each handles one target. "We get positional accuracies on the screen to plus or minus one minute of arc," Gullen says. "That's one-sixteenth inch at our viewing distance, and it makes sure that aircraft land on runways, not on taxiways or grass.

"The aircraft images are more resolute than the human eye can see, forty seconds of arc per optical line pair," he adds. "Even when you look through binoculars, the images are crisp and sharp."

Software engineers created those images by starting with precise models 1/64 scale and smaller. "We taped polygons on the models, then used a 3-D digitizer to put them into the system," says engineer Tom Bedford. "We digitized each polygon separately. That gave us the control to make the images absolutely real."

Once the targets are in the computer, image generators move and turn them in perfect perspective, according to how the voice side of the TOTS system interprets a controller's spoken instructions. Kaiser Electro-Optics of San Diego achieved ultra-high resolution by modifying Electrohome 2000 video projectors designed for wall-size screens. Kaiser's custom optics compress images to sizes ranging from a dot in the distance to a maximum of 11 inches as a DC-10 taxis past the tower. Even that faraway dot is a recognizable aircraft through binoculars.

"That was just one part of our process," Gullen says. "The projectors are mounted in two stacks of five on the roof of the cab, and obviously none of them can be at the exact center of things. When you're projecting onto the inside of a dome, that normally causes keystoning, or trapezoidal distortion. In our case, it was complicated even more, because our projector head moves in both azimuth and elevation."

Gullen's team calculated the varieties of distortion and wrote computer algorithms that built corrections into the computer-generated images. The final algorithms handled every possibility, yielding a still image that is updated 30 times per second. "Each image gets projected twice, giving us a flicker-free image that the eye sees as continuous motion," Gullen says. Moving targets look perfect in aspect ratios, motion, size, and even color correction to student controllers inside the tower cab.

"We had to mathematically map out all the curves on the screen to keep everything in focus," Bedford says. "Our depth of field was between one-quarter and one-half inch. The difference between sharp focus and being just a little off would really stand out if we had missed."

In tandem with the imaging team, the project's voice team confronted its own challenges. First they studied FAA tower communications and determined that 260 words covered almost all communication that is normally exchanged between pilots and controllers. That established the vocabulary.

"It gives us thousands of possible commands," team leader Cathy Meyn says. "But they're precise. It's frightening to think that people can die because you don't use the right words."

Engineers chose an ITT 1280 voice recognition/response board to be integrated into the Sun computers, then set about developing the special software needed to make everything work together. The first step is for the board to recognize spoken words. Students go through a session lasting up to two hours in which they read the words and phrases to be used during TOTS exercises. In effect, the session trains the computer to recognize how each person says the 260 words in the vocabulary.

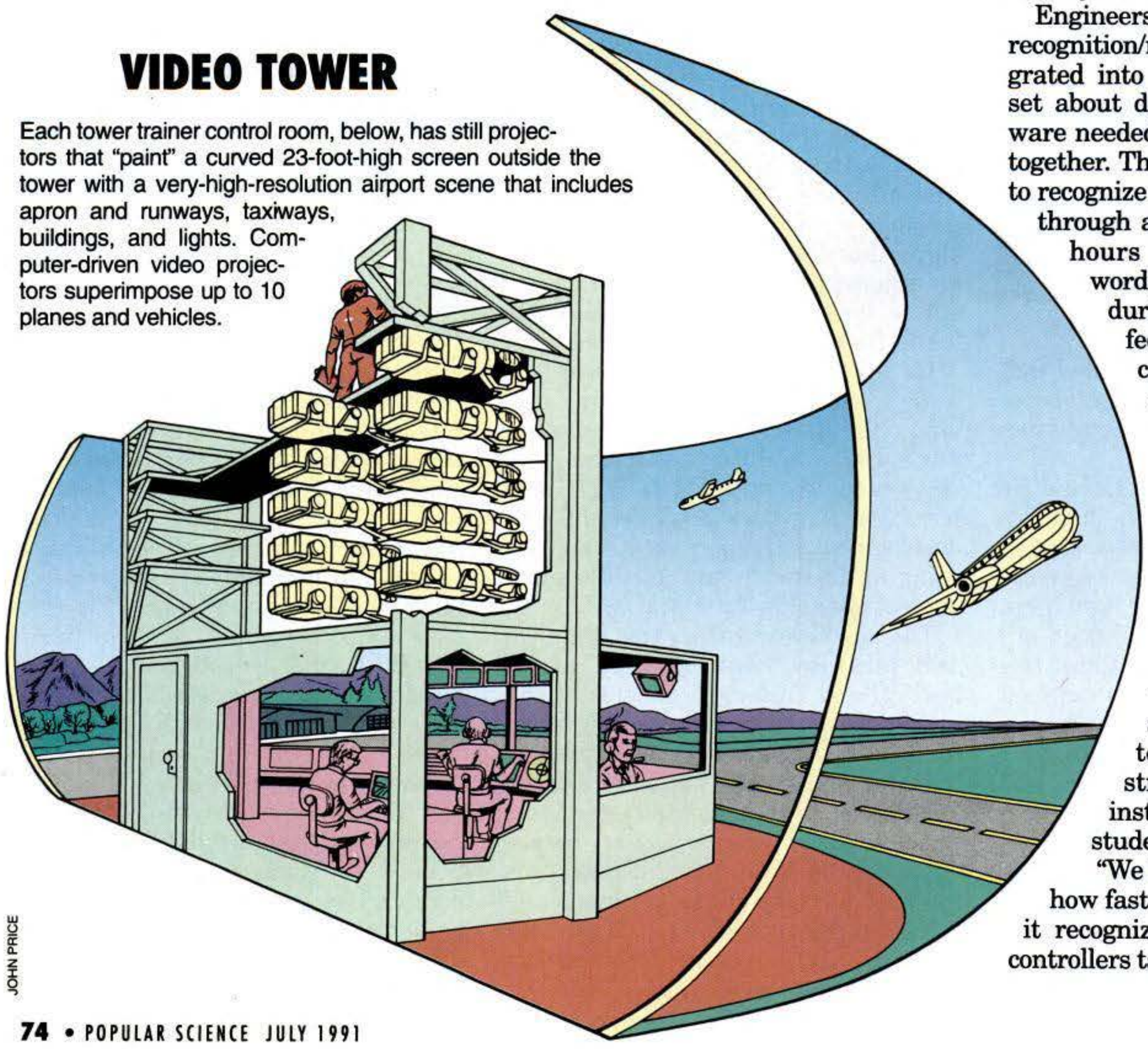
Each word is converted from an analog to a digital signal, cut into time slices, and broken down into eight separate frequencies. From that the computer creates word-by-word reference templates unique to each student. It uses those later to sample a student's instructions to pilots, almost instantly determining what a student just said.

"We built in some flexibility on how fast you can talk and still have it recognized," Meyn says, "because controllers talk faster or slower depend-

[*Continued on page 86*]

## VIDEO TOWER

Each tower trainer control room, below, has still projectors that "paint" a curved 23-foot-high screen outside the tower with a very-high-resolution airport scene that includes apron and runways, taxiways, buildings, and lights. Computer-driven video projectors superimpose up to 10 planes and vehicles.



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**GEO STORM GSi**

**HYUNDAI SCOUPE LS**

**NISSAN NX 2000**

**SATURN SC**

These four affordable coupes take on the open road with room for two and a few kids, groceries, or a small dog. All have respectable fuel-efficiency ratings, while multivalve engines and five-speed gearboxes add up to performance beyond their means.

# GETAWAY COUPES

By JIM McCRAW

The premise here is simple: Small cars do not have to lack fun, character, and value just because of their size. These days, you don't have to spend a mountain of money to buy a small car sized for two-plus with good balance, good equipment, built-in joie de vivre, and visual distinction.

The best examples of the new genre in 1991 come from Chevrolet's Geo division, General Motors' Saturn division, Hyundai, and Nissan. The quartet ranges from the jampacked Nissan NX 2000, the smallest car with the highest price ($15,420 as tested), available with a package that includes both an air bag and antilock brakes, to the Hyundai Scoupe LS, which can be delivered with substantial equipment (although no air bag or antilock brakes) for almost $4,400 less. The middle range of the test group's price spectrum is occupied by the Geo Storm GSi and the Saturn SC sport coupe.

The test team lived with this foursome for a few weeks—thrashed them severely at POPULAR SCIENCE's Michigan testing center, hit the back roads with them, bought groceries, and took them to the mall.

A front-drive sporty coupe genealogically related to the Isuzu Impulse, the Storm is a style setter in its own right, bearing more than a passing resemblance to its bigger, tougher brother, the Saturn Coupe. The Storm's fun-loving Isuzu heart beats in an aggressive, cute cartoon car with appealing looks that are much more dramatic when the car is painted in "Hi, sailor" yellow, as the test car was.

Underneath the shiny yellow exterior is a package almost 164 inches long equipped with a 130-horsepower 1.6-liter four-cylinder engine—a 12-valve double-overhead-cam design with electronic multi-point fuel injection. Rated by the EPA at 25-mpg city, 33-mph highway, the Storm demonstrated good flexibility around town, but was not happy when cold—exhibiting shaky, noisy, and loud behavior for the first few minutes on brisk mornings. It also was the loudest of the group when accelerating and tied with the Saturn coupe for overall interior noise level at speed.

The Storm's slick five-speed manual transmission is matched by a nice, light clutch action. But despite a good power-to-weight ratio, the Storm came in second slowest in the group, ahead of only the sluggish Scoupe, although it produced consistent sub-10-second 0-to-60-mph runs. The high-rpm, low-torque small-displacement engine displayed a readiness to visit 7,000 rpm again and again.

The Storm GSi's high-backed bucket seats are comfortable yet body grabbing when they need to be. The instrument panel is a deeply tunneled information display and a marvel of ergonomics, with fingertip switches aplenty and gauges that are easy to live with and look at. The materials used on the seats and interior panels are well finished and tightly screwed together. The steering wheel, which contains an air bag as standard equipment, could use a tilt feature to accommodate taller drivers. As always on a good Japanese coupe, there are plenty of places to stash small items.

Armed with P205/50VR-15 tires, 15-inch wheels, an all-strut suspension, and a 96.5-inch wheelbase, the Storm had no trouble changing direction and pulled a respectable second-place 0.84-g lateral acceleration—behind the sticky Nissan NX 2000—on the skid pad, with second place marks in the lane-change and slalom maneuvers too. The Storm's power rack-and-pinion steering is medium quick at 16:1, with a fairly heavy feel that adds confidence. And



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The Nissan NX 2000 coupe combines a tidy cockpit and a compact exterior with a best-in-its-class 140-hp multivalve power plant.

PHOTOS BY JOHN B. CARNETT/TAKEN AT SIX FLAGS GREAT ADVENTURE IN JACKSON, N.J.



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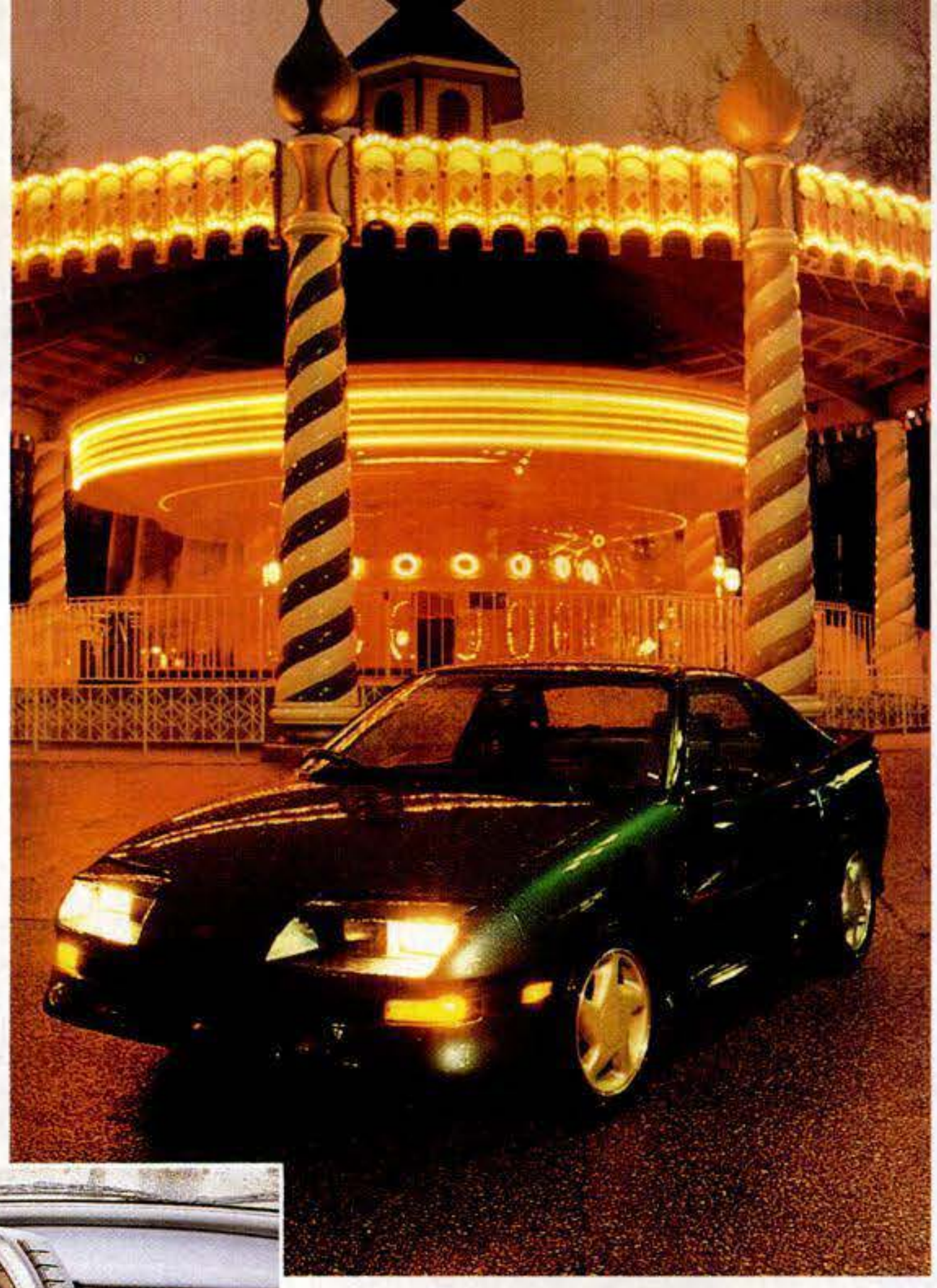


The Geo Storm GSi is a compact, spirited, and slightly cramped two-seater with a free-revving engine and an interior designed for clean living.

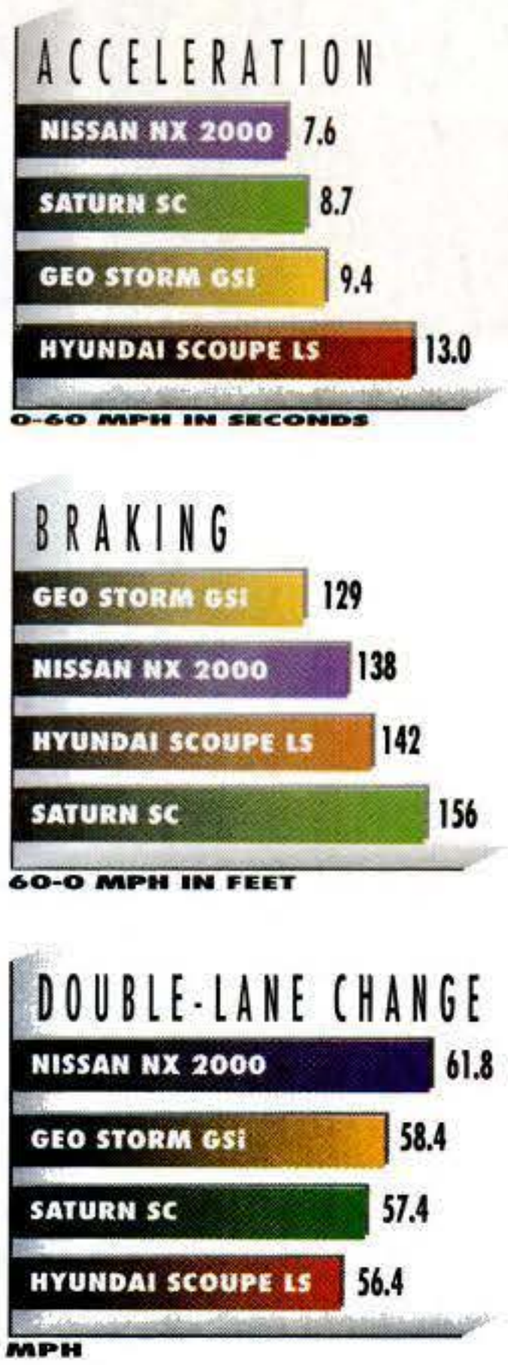
the efficient power disc/drum brakes provided by far the best warm and hot stopping distances of the test for the nearly 2,500-pound coupe.

Hyundai's Scoupe LS is built on the Excel's mechanicals and platform. At 165.9 inches, it is almost 2.5 inches longer than the Geo. Power is supplied by a Mitsubishi-built 1.5-liter multipoint fuel-injection engine, transversely mounted and driving the front wheels. The engine is only slightly smaller than the Storm's but delivers a meager 81 hp at 5,500 rpm, inadvertently demonstrating the relative inefficiency of its two valves per cylinder compared with the Storm's twin cams and four valves per cylinder.

The Scoupe's engine is noisy, and the car's 13-second 0-to-60-mph time was simply outclassed by the other cars in the group. The good news is a respectable 26/34 mpg EPA mileage rating. The Scoupe has a five-speed manual transaxle and power front disc brakes. Hyundai offers a four-speed overdrive electronic-control automatic transaxle with dual-mode shifting.

The Scoupe LS incorporates many gadgets, from bronze-tint glass to power windows and mirrors to remote releases, consoles, and headrests and a six-way driver's seat. It's all screwed together pretty well into a body shell designed by Giorgetto Giugiaro's Ital-Design company in Turin, Italy. With big scooped-out wheel wells to show off its relatively narrow P185/60HR-14 Michelin radials, the Scoupe is handsome, if a trifle unadorned.

The front strut and rear trailing-arm suspension in the Scoupe is tuned by Lotus Engineering, with power an option for the rack-and-pinion steering. I found the LS to be nimble, comfortable, and competent. The controls and instruments are well done, the shifter is quite slick, and there are no major gaffes in ergonomics. The power steering is a little on the light side, but plenty welcome for parking situations. The materials used for the Scoupe interior are good, not great, in quality and feel.




Overall, the Scoupe needs more power. The little 1.5-liter engine works hard and is loud when pushed, but it's economical and mechanically simple. The Scoupe's tuned-by-Lotus suspension was fine on the skid pad, with a 0.82-g score, but the car never felt sorted out on the slalom or the lane-change excursions, finishing last in both tests.

The bargain-basement Scoupe manages to undercut the price-to-value relationship represented by the Saturn SC sport coupe, GM's latest car to be built with a space frame—steel and plastic body panels. The Saturn's all-aluminum 123-hp 1.9-liter twin-cam engine certainly fits into this size/price class at the top, with its 99.2-inch wheelbase and length just under 176 inches. This was my first encounter with a production Saturn coupe, and it was better than earlier prototypes in terms of noise, vibration, overall quality of finish, and performance.

The basic SC sport coupe version of GM's latest plastic-car design starts roughly on par with the fully equipped Hyundai, with a generous GM-style standard equipment list roughly comparable to that of that the Saturn SL2 sedan. The coupe is rated by the EPA at 24 mpg in the city and 34 mpg on the highway.

The SC's solid performance envelope is a mixed bag, marred mainly by a relatively long stopping distance. Otherwise, the car's 8.7-second 0-to-60-mph time was second quickest, and its 0.82-g skid-pad showing was quite respectable, tied with the Hyundai. The 2,389-pound Saturn coupe has P195/60R-15 tires for better braking ability and the best overall weight distribution, 62:38 percent front to rear.

The Saturn coupe provides a pleasant visual interior environment, with



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instruments, controls, and other elements nicely blended. Instrument panel graphics are weak, and the seats are somewhat flat, with little side support. In daily use, the SC was a pretty good soldier, with handsome looks and respectable overall handling its strongest suits. The car always seemed solidly glued to the road, a feeling complemented by a nicely designed steering wheel and variable-effort power steering system. The suspension on the sport coupe is stiff and makes for a fairly rough ride, but the flip side is that it's fun to drive quickly. It turns in well, and doesn't rock around a lot when making large direction changes. The shifter is functionally OK, but not yet wonderful, and the engine pulls well.

The Saturn's aural environment, however, still needs a good deal of work. The engine, transmission, suspension, and tires still create a symphony of dissonance inside the car that needs to be orchestrated.

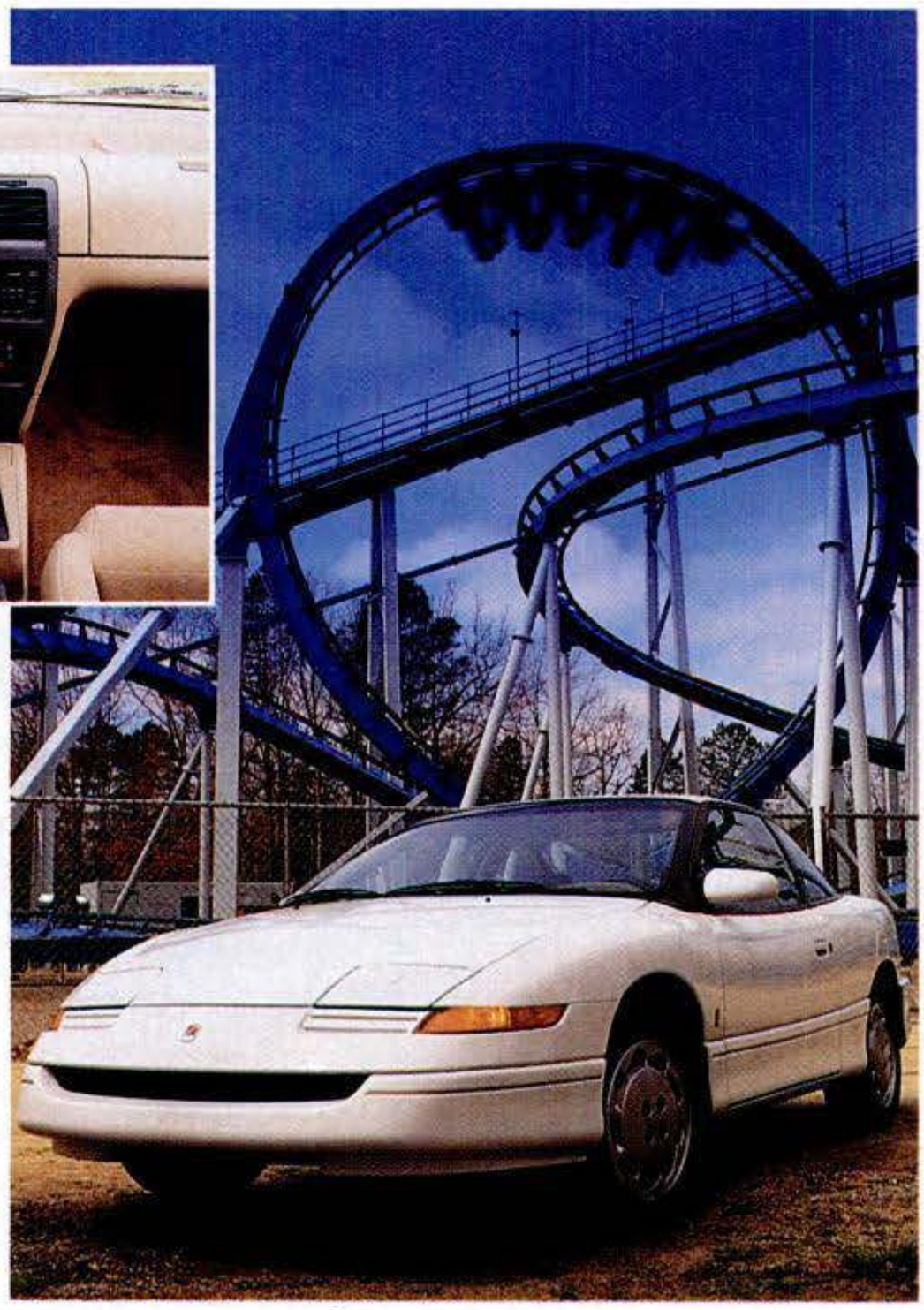
In marked contrast to the years of anticipation that preceded the introduction of the Saturn, the Nissan NX 2000 was something of a surprise. A replacement for the Pulsar NX, the NX 2000 just hit the showrooms midwinter in the United States, an aero-hatch version of the new Sentra SE-R, with 140 hp from its two-liter 16-valve engine. (It's also available as an NX 1600 with a 110-hp 1.6-liter four-valve engine.)

The all-alloy Nissan two-liter engine, which generated an EPA rating of 23 mpg in the city and 31 mpg on the highway, is fitted with a premium sequential electronic multi-point fuel-injection engine and matched with a slick five-speed transaxle.

The Sentra SE-R has gathered a great deal of praise for its performance and sophistication, and so should the hatchback coupe version. The interior of this car is beautifully put together in white-on-black instruments and gray tweed upholstery, with Nissan/Infiniti's new trademark ovoid shapes reinforcing the body shape and lighting treatments on the outside. The seats are comfortable and supportive on both straight and twisty roads, and instrument comprehension is excellent. Even with a T-bar roof, there is room up front, but not in the back (a trait shared by all four cars).

Hyundai's Scoupe LS offsets moderate performance with maximum interior room, a high level of equipment, and low cost.

The slick, wet-look finish on GM's Saturn Coupe SC covers the all-thermoplastic body panels supported by a steel space frame.



No slouch out there on the testing tarmac, the NX 2000 has the best power-to-weight ratio in the group, and managed 0-to-60 mph in only 7.6 seconds, with the best overall skid-pad performance at 0.85 g—a high number, indeed—best slalom speed, best triple-lane-change, and good braking with its ABS at 138 feet from 60-to-0 mph, dominant performance from a nicely put-together package. The NX 2000 is the smallest package of the four, with only a 95.7-inch wheelbase and an overall length of 162.4 inches. It's also the heaviest, at 2,674 pounds, with the weight concentrated in the nose.

Helping the NX 2000 reach those levels of performance is an all-strut suspension, power rack-and-pinion steering, front and rear stabilizer bars, P195/55R-14 tires, and a standard viscous limited-slip differential, a combination of ingredients that helps to balance the car well in quick maneuvers. The NX 2000 was simply head and shoulders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above the others in terms of dynamics.

Whether it's to be a third car, teenager's car, college car, or first car, all four get a high fun factor, parkability, good mileage, good insurance rates, and small monthly payments as standard equipment, along with some new-tech equipment, such as ABS and air bags. Of this crop of new-on-the-market sporty coupes, though, the pick is certainly the NX 2000, a new standard of goodness in a small package. PS

## COUNTERPOINT

This is our second go-around with General Motors' new Saturn car line, which has been improving so fast since the first pre-production cars were shown to the press that it reminds me of a bride walking down the aisle with a dressmaker still working on the gown. To take the analogy a bit further, Nissan's new NX 2000 comes crashing into the church during the ceremony, making the groom have second thoughts.

The Saturn coupe has many visible virtues, notably overall handling and performance that ranks it close to the top in its class, and one major audible flaw—an engine that, in its twin-cam form, isn't so much noisy as unpleasantly raucous, which diminishes its basic virtue—gutsy, flexible power. It probably isn't a coincidence that the same problem plagued early versions of the Geo Storm—likewise a product of the GM development process, despite its Japanese origins—which today is still loud but more melodic.

The Saturn has hidden virtues too, including a tough, completely rust-free body, which has been engineered to weigh less than the Storm's, despite being a larger car overall. I give it high marks for ergonomics, great seats, and one of the best-finessed transmission-clutch pairings in the business.

The GM kinship between the Saturn Coupe and the Geo Storm quickly leads to direct comparison, but the Saturn is simply more car for about the same amount of money. The Storm is smaller, slower, and sometimes suffers from twitchy handling. The standard air bag in the Storm is no small comfort, however, and today's overall Storm package is balanced and refined.

The Hyundai Scoupe often struggles to keep up with this group, despite its laundry list of options and a price tag that barely clears five figures. Mainly, it's another pretty face. Pressed hard, the suspension and brakes go soft, and the undersized engine runs short of breath in normal traffic.

All of which leads to the new NX 2000—in exterior appearance something of a frog in need of a few kisses, but exuding a fine balance of handling, ride, free-revving acceleration, and progressive, controllable braking that makes driving enjoyable.

Overall, exactly what a fun, small coupe is all about.—*Dan McCosh*

## POPULAR SCIENCE TEST RESULTS

| | Geo Storm GSi | Hyundai Scoupe LS | Nissan NX 2000 | Saturn SC |
|---|---|---|---|---|
| **ACCELERATION and HANDLING** | | | | |
| 0-30 mph (sec.) | 3.0 | 2.7 | 3.8 | 3.1 |
| 0-60 mph (sec.) | 8.7 | 7.6 | 13.0 | 9.4 |
| 30-50 mph (sec.) | 11.7 | 9.7 | 11.7 | 12.4 |
| 50-70 mph (sec.) | 11.8 | 10.1 | 13.7 | 13.4 |
| Double-lane change (mph) | 57.4 | 61.8 | 56.4 | 58.4 |
| Slalom (mph) | 47.5 | 49.3 | 45.9 | 48.0 |
| Road-holding (g) | 0.82 | 0.85 | 0.82 | 0.84 |
| **BRAKES** | | | | |
| 60-0 mph cold (ft.) | 166 | 142 | 159 | 154 |
| 60-0 mph warm (ft.) | 156 | 138 | 142 | 129 |
| 60-0 mph hot (ft.) | 149 | 142 | 144 | 131 |
| **INTERIOR NOISE** | | | | |
| Idle (dBA) | 52 | 48 | 45 | 49 |
| 60 mph (dBA) | 70 | 69 | 69 | 70 |
| 0-60 mph (dBA) | 80 | 78 | 79 | 81 |
| **SPECIFICATIONS** | | | | |
| Engine | 1.9L I4 | 2.0L I4 | 1.5L I4 | 1.6L I4 |
| Valve train | DOHC | DOHC | SOHC | DOHC |
| Power (hp @ rpm) | 123 @6,000 | 140 @ 6,400 | 81 @ 5,500 | 130 @ 7,000 |
| Torque (lb.-ft. @ rpm) | 121 @4,800 | 130 @ 4,800 | 91 @ 3,000 | 102 @ 5,800 |
| Compression ratio | 9.5:1 | 9.5:1 | 9.4:1 | 9.8:1 |
| Transmission | 5-speed manual | 5-speed manual | 5-speed manual | 5-speed manual |
| Final drive ratio | 4.06:1 | 4.17:1 | 4.32:1 | 4.12:1 |
| **CHASSIS** | | | | |
| Front suspension | MacPherson strut, anti-roll bar | MacPherson strut, lateral link, anti-roll bar, stabilizer bar | MacPherson strut, anti-roll bar | MacPherson strut |
| Rear suspension | Independent, strut-type, trailing and lateral links | Independent, strut-type with parallel links, stabilizer bar | Trailing arm, anti-roll bar | Independent, strut-type |
| Steering gear | Rack-and-pinion | Rack-and-pinion | Rack-and-pinion | Rack-and-pinion |
| Turning circle (ft.) | 37.0 | 34.1 | 31.7 | 32.2 |
| Brakes | Disc, drum | ABS; disc, disc | Disc, drum | Disc, drum |
| **EPA MILEAGE** | | | | |
| City | 24 | 23 | 26 | 25 |
| Highway | 34 | 31 | 34 | 33 |
| **DIMENSIONS** | | | | |
| Wheelbase (in.) | 99.2 | 95.7 | 93.8 | 96.5 |
| Length (in.) | 175.8 | 162.4 | 165.9 | 163.4 |
| Width (in.) | 67.5 | 66.1 | 64.0 | 66.7 |
| Height (in.) | 50.6 | 51.4 | 50.0 | 51.1 |
| Curb weight (lbs.)/distribution (% front: rear) | 2,389/ 62:38 | 2,674/ 64:36 | 2,270/ 63:37 | 2,495/ 63:37 |
| Fuel tank (gal.) | 13.2 | 13.2 | 11.9 | 12.4 |
| Interior volume (cu. ft.) | 76.4 | 55.7 | 79.9 | 78.4 |
| Trunk volume (cu. ft.) | 10.9 | 16.9 | 9.2 | 11.0 |
| **PRICES, PARTS, AND LABOR** | | | | |
| Base price | $11,775 | $12,970 | $9,745 | $12,395 |
| Price as tested | $13,500 | $15,420 | $11,065 | $13,225 |
| Major options (over $100) | Option package B: air conditioning, power locks, windows, and mirrors, cruise control $1,430; AM-FM cassette $295 | T-bar roof $900; air conditioning $850; antilock brakes $700 | Air conditioning, alloy wheels, AM-FM cassette, sun roof, power steering $1,320 | Air conditioning $690; AM-FM cassette/clock $140 |
| **REPAIR: PARTS/LABOR*** | | | | |
| Brake pads | $ 42/0.6 | $ 35/0.7 | $ 33/0.3 | $ 36/0.7 |
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| Windshield | 640/2.9 | 402/2.7 | 276/N.A.† | 362/1.2 |
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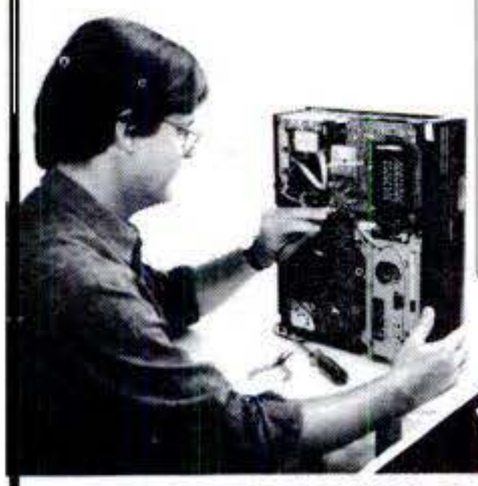

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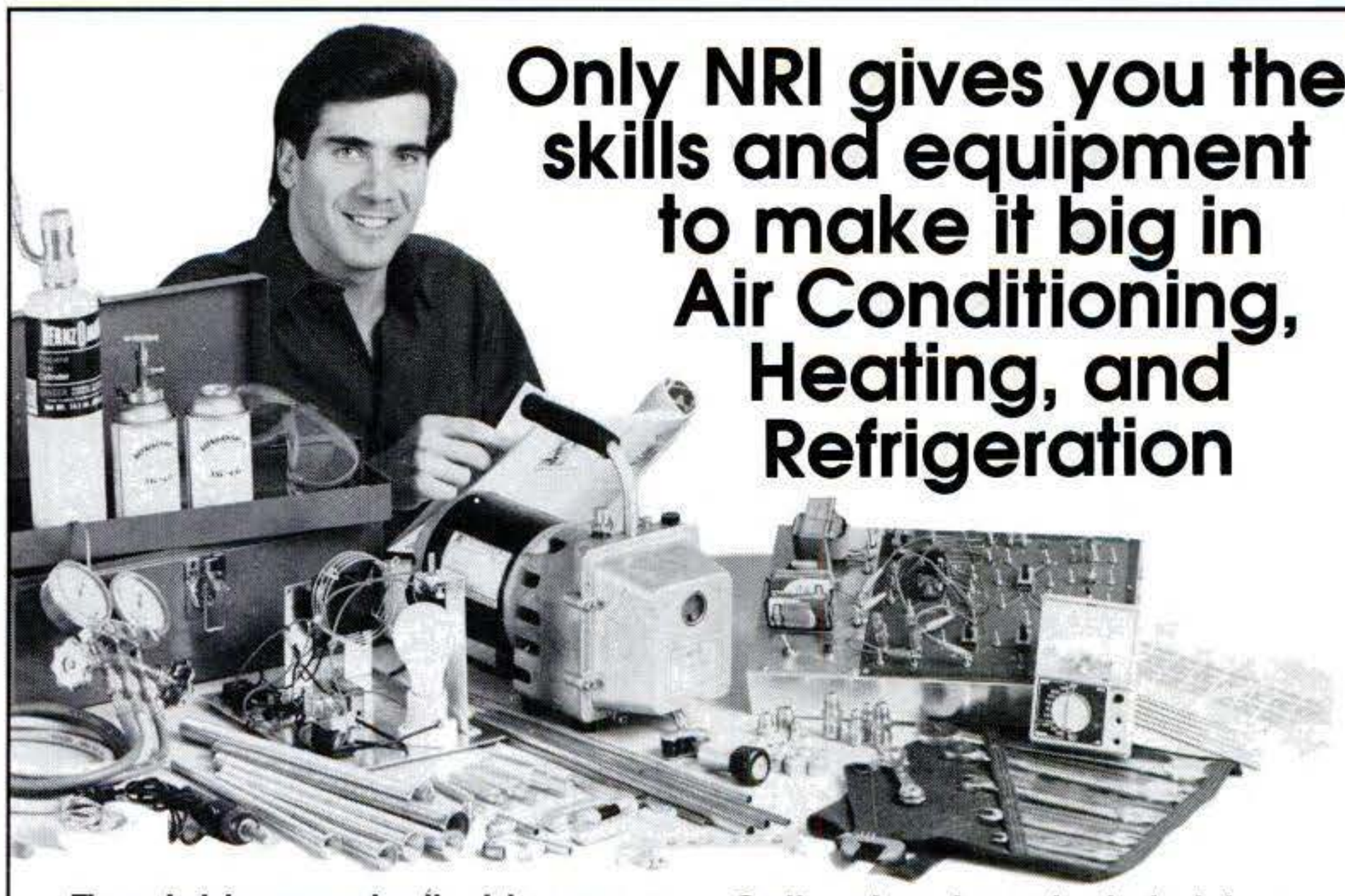

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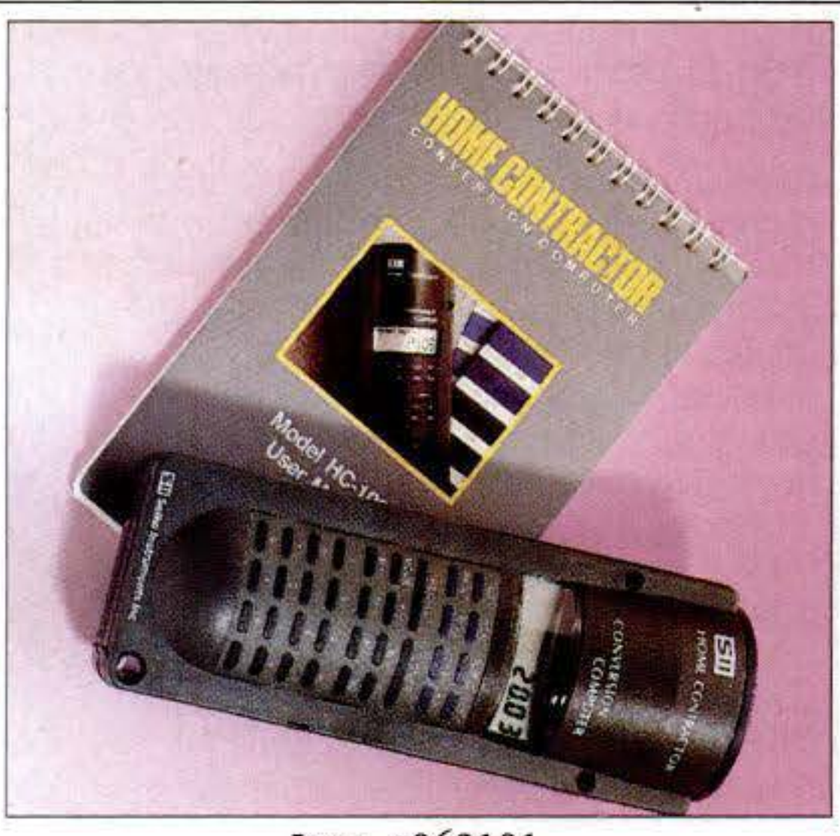


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## Electric car showdown

[*Continued from page 65*]

nia and a specialist in metal-air batteries, says there are three main approaches to preventing dendrites. One is to increase the zinc surface area, which reduces the local current density; another is to circulate the electrolyte in the battery, which prevents local concentration gradients of dissolved electrolytes; the third is to use a tough ceramic, such as zirconium oxide, for the battery separators to reduce dendrite damage.

"I can safely say dendrites are no longer a problem," says Ross.

Equally important in solving zinc-air problems is a computer-controlled air manager that regulates the humidity and $CO_2$ content of the air reaching the batteries. Air for the batteries is humidified and passed through a scrubber to remove $CO_2$. The scrubber uses lithium hydroxide (LiOH). The LiOH is not used up in the process and can be reconstituted by heat or chemical means. A separate airstream passes around the batteries to keep them cool. The air manager also regulates how much air is passed over the battery cathodes, holding it to between 4 and 10 times what the reaction needs. When the battery isn't being used, the air is shut off.

The current-supply problem is more difficult to solve. Basically the output of a zinc-air battery is limited by the surface area of the carbon cathode. The CRX carried nickel-cadmium batteries to handle burst-power requirements. The DEMI researchers hope to eliminate the burst-power batteries with more zinc-air development.

### A 20,000-mile guarantee

Energy density aside, the other critical factors in a practical electric car battery are life and cost. While the life of the cells depends on such factors as rate of charge and discharge and depth of discharge, DEMI says current zinc-air batteries should last 20,000 miles, making them cost competitive with gasoline at $2 a gallon. Assuming service life can be increased to 35,000 miles, the batteries become competitive with gasoline at $1.25 a gallon.

Danczyk says that zinc-air battery packs could retail for $1,500 to $2,500. Potentially, he says, zinc-air batteries can be made for about half the cost per kilowatt-hour of lead-acid batteries. And the components of zinc-air cells are less damaging to the environment than those of other batteries.

Although there is still work to be done, Danczyk is confident. "We don't see any 'gotchas' with the technology in bringing out a consumer-acceptable electric vehicle," he says. "It's basically straightforward engineering." PS



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genetic analysis, tensions between the interests of individuals and those of employers and insurers will become increasingly severe," he says.

Foreseeing those objections, the genome project is allocating two percent of its budget for studies of ethical, legal, and social considerations. An advisory committee already has laid out a coordinated program of study and education to deal with those problems. One of the people on that committee was Jonathan Beckwith, a molecular biologist at Harvard who is a leader of Science for the People, a determinedly anti-establishment group that has often protested about neglect of human values in science.

"The funny thing is that in my mind, the importance of the genome project is exaggerated in terms of social consequences," Beckwith says. "A lot of the things I'm worrying about are happening independently of the genome project. In that sense I'm pleased by the project, because it's the first time that funding has been provided to think about social consequences at the same time that a project is funded. I think it's a good precedent."

An entirely different problem that concerns people in the project is data storage and management. It's not so much putting the data into computers—"Anyone can store three billion bits of information," one scientist says—as developing methods to make it usable. Data bases are being set up in several places, including Johns Hopkins University and Los Alamos National Laboratory. But much of the informational work for the project is being done in Bethesda, Md., at the National Library of Medicine's Center for Biomedical Technology—which, curiously enough, isn't an official part of the project.

"You can't just waft it into the computer someplace and leave it there," says David Lipman, director of the center. "You have to come up with new hybrid ideas. You have to understand at the intuitive level what biologists want to ask. In past searches of the data, just experts were doing it. Now every molecular biologist has to be able to do sophisticated searches on his own, or you don't get the maximum out of the data. Some people want to throw up their arms and say the computer problems are going to be impossible. I don't think that's true. I'm confident it's doable."

One measure of the difficulty is in the size of the first genome project data base being prepared by the center. It will be too big to go on one CD-ROM, which can handle an ordinary encyclopedia with no problem, Lipman says. "We'll be making CD-ROMs with a variety of information on them, but we'll have to set up the data in various ways."

## Chips for genes

Hood is also working on genome computer technology. He's already got one microchip, derived from space science, that's superfast at searching through genetic sequences to find matching patterns. He and researchers at the University of Southern California and the Jet Propulsion Laboratory in Pasadena, Calif., have just finished a second chip, being made by Hewlett-Packard, that is "ideal for searching for unknown patterns." Chips like those could pick genes out of a sea of nonsense DNA.

The genome initiative is the kind of challenge America has traditionally accepted. Says Hood: "If we aren't rich enough as a country and intellectually daring enough to do this, we're in disastrous shape for the future." PS

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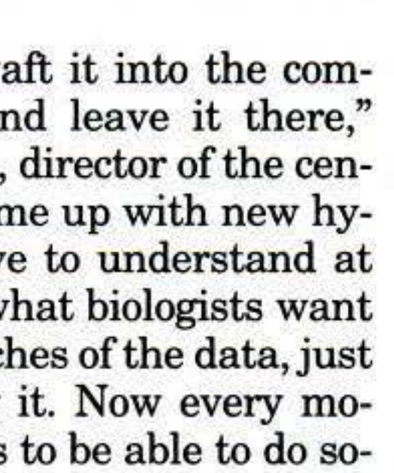

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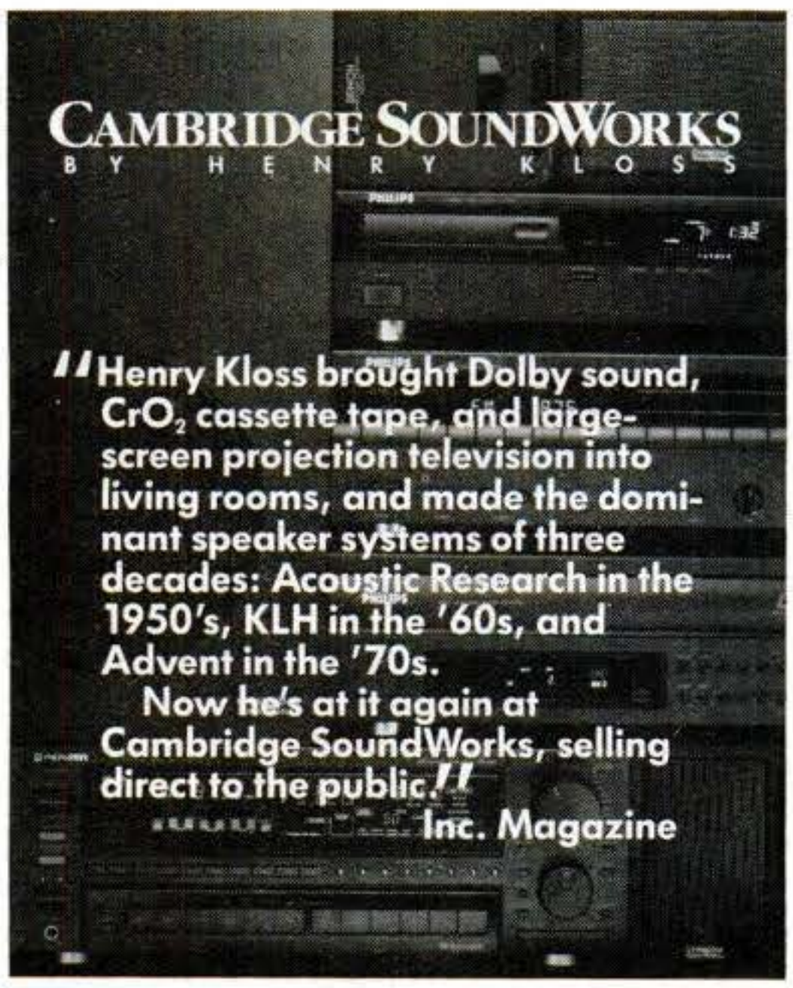
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## Technology race beneath the waves

[*Continued from page 54*]

with prolonged under-water training on a regulator, an athlete can sustain an output of 0.5 hp for at least 10 minutes.

The second discovery involved position and breathing. Poole's work with MIT's Dave Wilson (who originated the recumbent bicycle) determined that an inverse recumbent 140-degree bend with small-of-the-back support is the optimal position for underwater-power people. And the breathing secret is to position the scuba regulator at or slightly below the level of the lungs. With the regulator higher, extra, exhausting work is needed to get air into the pedaler's lungs.

Says Poole: "The *Squid*'s hull was built with systems integrated into it. This time I figured the maximum power available at 0.5 horsepower and integrated everything around that." The result is a 10-foot-long machine of singular design and function.

### Sub with a twist

*Subdue* has the now-traditional fiberglass/foam/fiberglass body, but with a twist. The inside has been sculpted to reduce weight, and ribs have been added only in stress areas. This minimizes ballast needs and helps reduce size. The drag from the fins, dive planes, and rudders is reduced by extending them from inside the body only when needed. But where *Subdue* truly shines is in its propulsion mechanism. At the Naval Academy's cavernous model shop, the just-finished body is lying belly up, as pale as a plucked chicken. Poole points out several features, including some details at the rear: a vertical, rectangular empty chamber with strengthening members and peculiar openings.

Then he and model-maker Boyer lift a 40-pound boxlike metal affair from a bench and neatly drop it into the empty chamber. Upside down, the mechanism is as exposed as an overturned horseshoe crab. And as interesting.

Nestled inside on metal "spiders" that are turned by gearing attached to standard bicycle pedals are two parallel sets of six paddle blades each. The apparatus is called a radially extended linear impeller propulsion (RELIP) mechanism. A two-to-one gear ratio between pedal and wheel provides the 70 rpm or so needed for ample thrust.

Poole explains that the paddles, four inches wide by nine inches long, are guided by cams in a perfect circle of travel. The paddles lie end to end except when eccentric cams at the start of the down stroke forces each in turn to an upright position. In such a posture, the paddle can grab a chunk of water, kick it backward, and then "lie back down" to reduce drag in the flooded chamber.

According to Poole, the RELIP has advantages. It is symmetrical and gives no side-to-side torque. Downward torque is compensated for by setting the shaft slightly below the centerline. And it's a snap to remove the entire mechanism for servicing. The only drawback is the somewhat complicated device in it.

Says Poole of his strokes of genius: "I figured we needed a quantum leap. Innovation brings risk, and that's why we're all doing this in the first place. Besides, it kicks some water."

### The five-knot solution

It turns out that Poole has a few more thoughts on the subject he has studied with such considerable intensity. These are the results in part of his natural bent and in part of students asking him, "How do you make a propeller? What size? How big are the controls? And how do you design a human-powered submarine?"

Out of Poole's research have come recommendations for what he calls the five-knot solution to the challenge of human-powered submarines, a challenge akin to the 20-foot pole vault or the four-minute mile. Poole calls for:

- A minimum-sized streamlined hull with a low drag coefficient and no more than 70 square feet of surface area.
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"I think of five knots as the asymptotic speed for subs, like the 20-knot challenge for human-powered surface vehicles on water," says Poole.

Whatever the outcome, with the technical wizardry, physical demands, and speeds reaching for the five-knot solution or better, this human-powered competition may be achieving cult status. And next time, who knows? But Poole throws out a thought full of promise, possibilities, and challenge:

"If I were to do Cal Gongwer's *Knuckle Ball*," he says, "I'd mate it with Ted Haselton's propeller. Then you'd see some real kickin'."

*The race course is in water six to seven meters (about 20 to 23 feet) deep in the Atlantic Ocean, several hundred yards off Singer Island, Fla. Following 100-meter time trials, there are four rounds culminating in the final race. Contestants race twice around an oval course for a total distance of 800 meters (about 2,625 feet). Predicted speeds range from two to about seven knots.* PS



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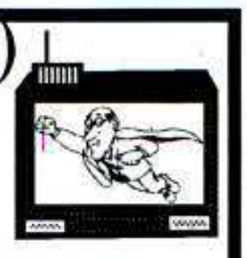

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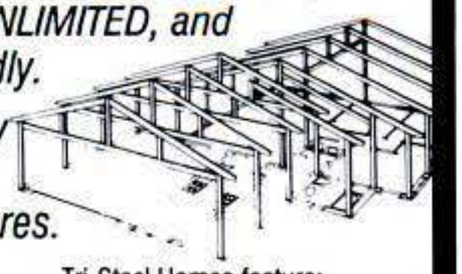

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## Air traffic training gets real [Continued from page 74]

ing on what's happening. Our system uses continuous speech, where your words bridge each other like normal conversation, as opposed to isolated speech where...you...talk...like...this. It's speaker dependent and syntax driven."

That means that the computer not only needs to be trained to recognize each student specifically but that its logic expects certain combinations of words. "For instance, it expects to hear a number after you say 'American' or 'United,'" Meyn explains. "If you say 'American 1,' it tracks. But if you say 'American Delta,' it could get confused. It would try to drive 'Delta' into a digit template, or it might drop the 'American' completely, particularly if the third word is a number."

That mirrors the real world. A controller saying "American...uh, Delta 123" would be recognized as issuing an instruction to Delta. A controller saying "American...uh, Delta cleared to land" would trigger a pilot's response from the computer: "Say again."

All responses from pseudopilots are real human voices. Logicon employees, both male and female, recorded appropriate phrases that are digitally stored in the computer and recalled as needed to create the correct communications flow between aircraft and tower.

"When the system recognizes a student controller's words, it outputs an action code," Meyn says. Part of that code prompts the audio response from pseudopilot to controller. Another part flashes into the visual algorithms, telling the computer what the aircraft is supposed to do next. That action is quickly calculated, new images are generated, and the controllers see aircraft respond. If the audio response is "Say again," however, there's no change in what the aircraft is doing.

### Faster certification

The FAA doesn't expect the new simulator to speed up the training period at the academy in Oklahoma City. "What it will do is reduce the time that controllers are on training status at their first tower assignments in the field," according to Hoppers. "Depending on the location, it can take more than a year of on-the-job training before a new controller is certified. Now that should be reduced to a matter of months."

TOTS will also help student controllers to prepare for and, it is hoped, avert tragedy and to handle routine operations. After going through an abbreviated voice training session with the TOTS computers in Oklahoma City, I spent some time directing aircraft into and out of Academy Airport. At one point, I had a United DC-10 waiting for takeoff as an American 727 approached on short final, already cleared to land.

I turned to Logicon's Herb Noll, who was serving as my instructor. "What would happen if I cleared United onto the runway right now?" I asked.

"Go ahead," he says. "Try it."

I keyed my mike. "United 433. Taxi into position. Cleared for takeoff."

"United 433..."

I watched the DC-10 begin to move, turning onto the runway directly in front of the rapidly approaching 727. As the aircraft merged, a huge orange fireball erupted on the screen. When it faded away, the planes were gone.

"We didn't program it for debris," Noll says. "The message is clear enough."

*Just one week later, a controller at Los Angeles International Airport cleared a commuter plane onto the runway in front of a landing USAir 737. Thirty-three people died.* PS


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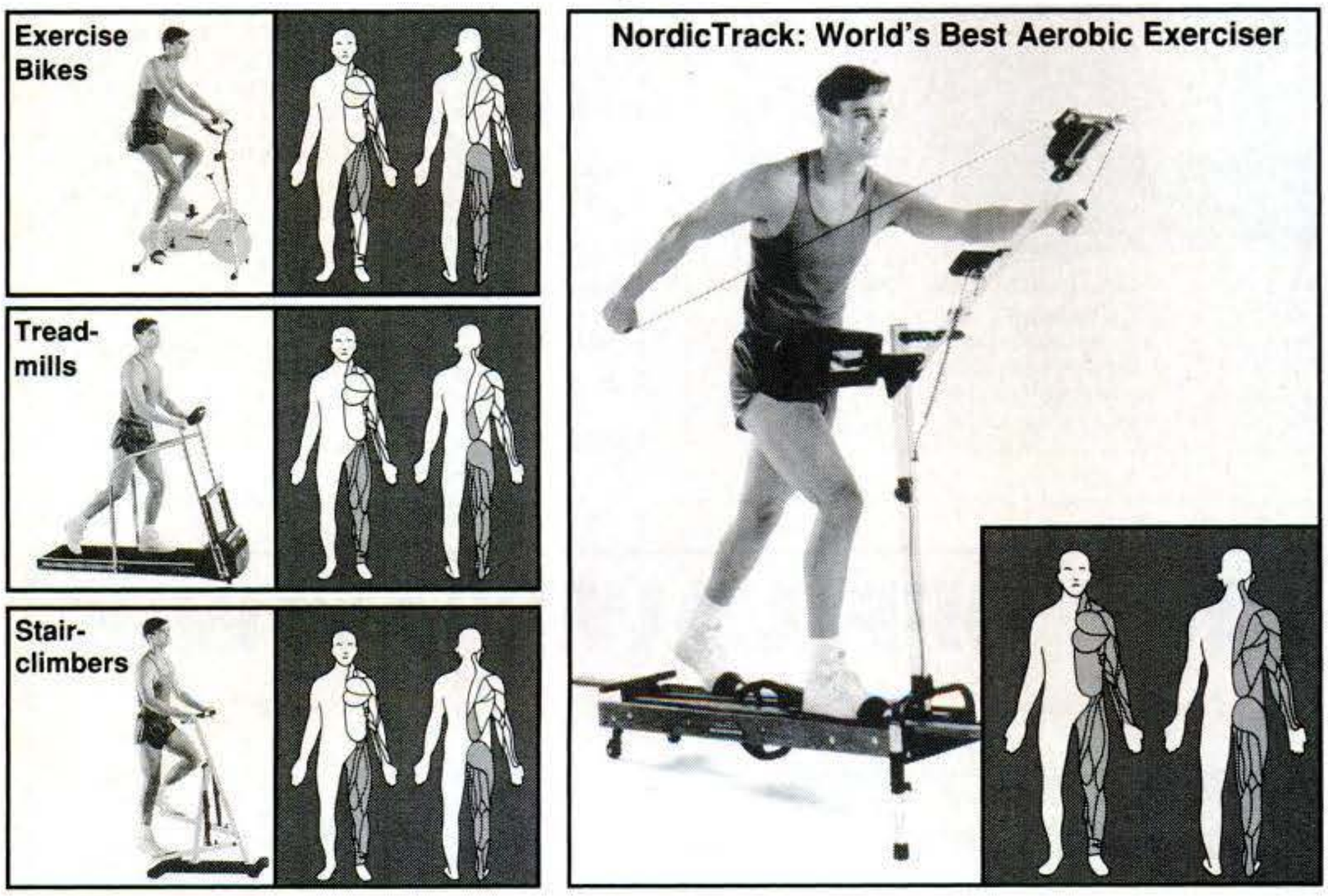


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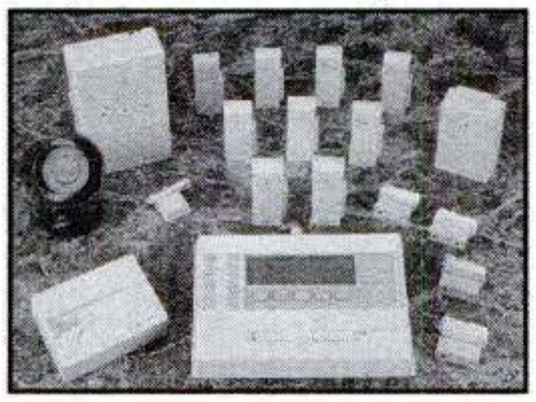

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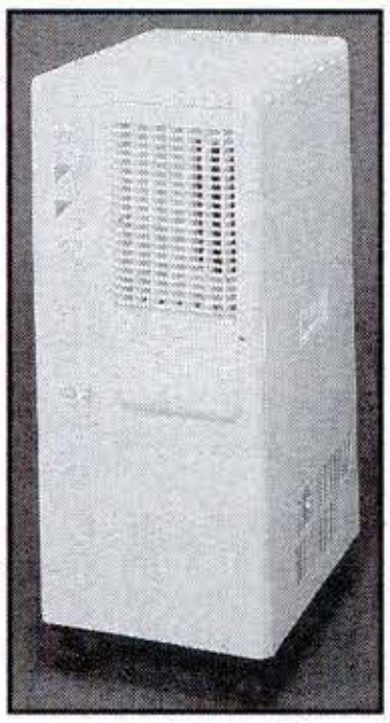

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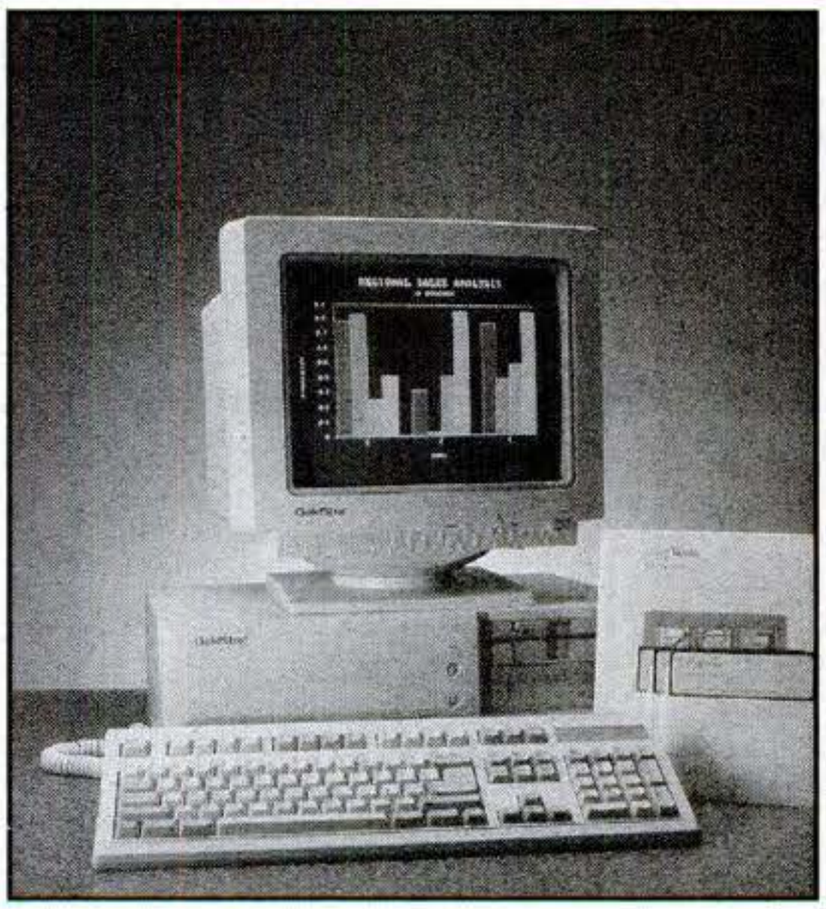

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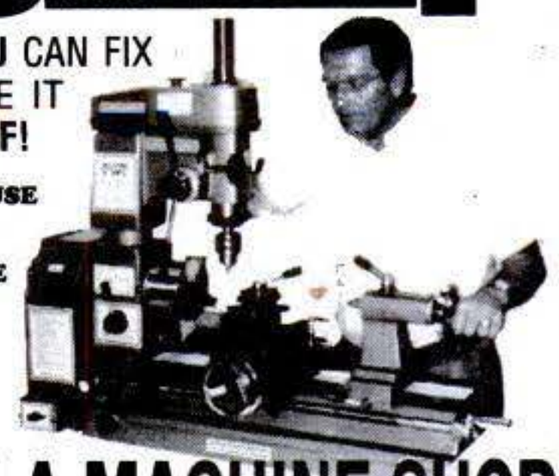

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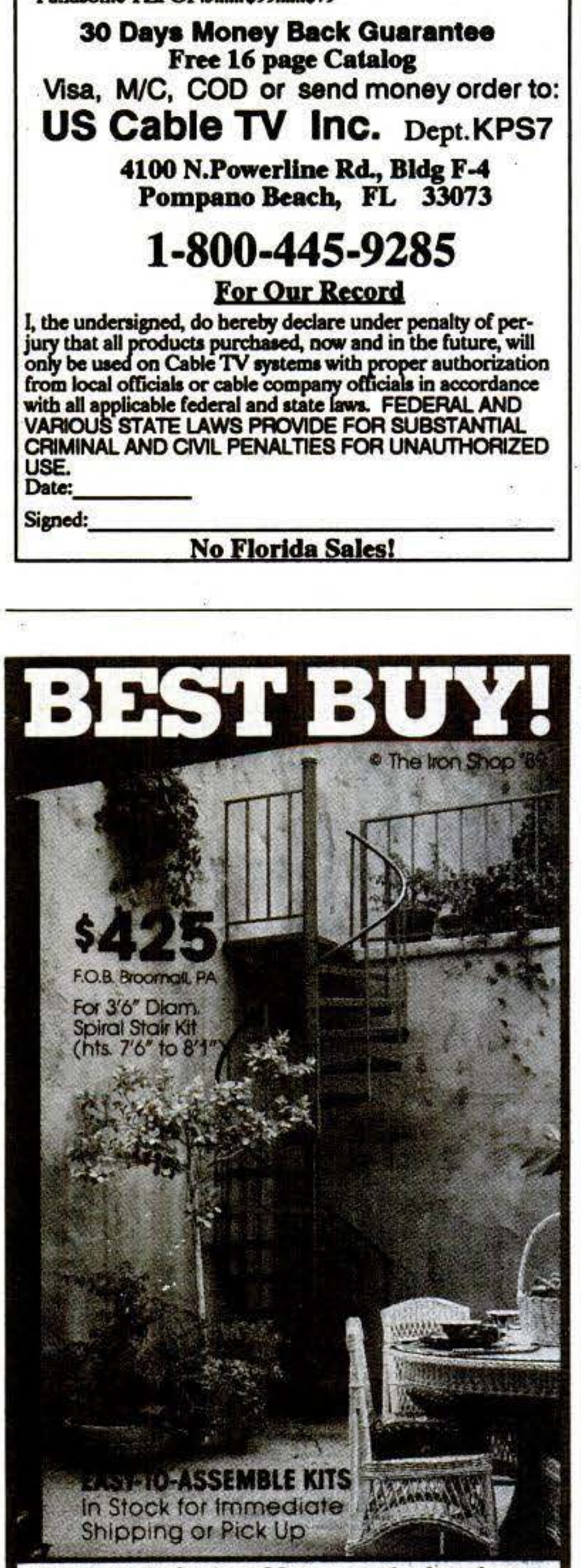
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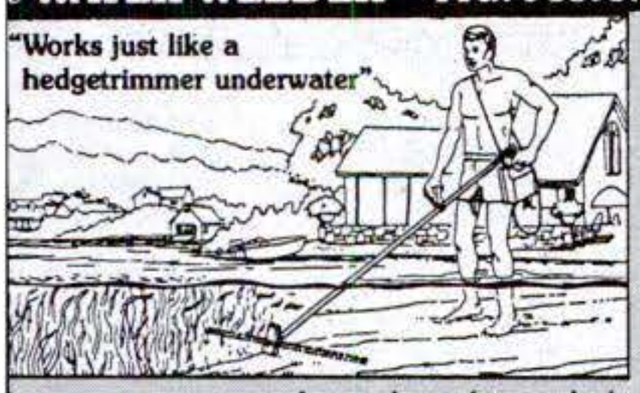

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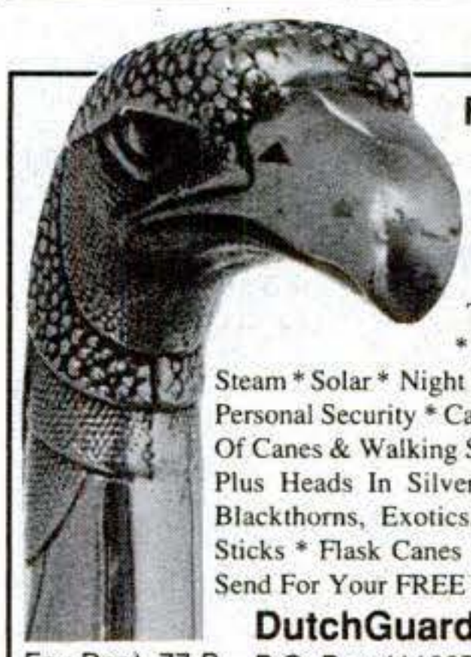

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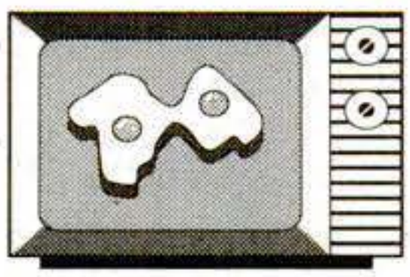

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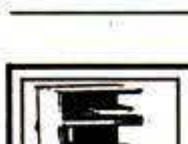

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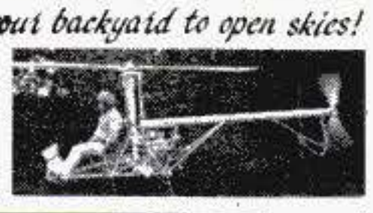

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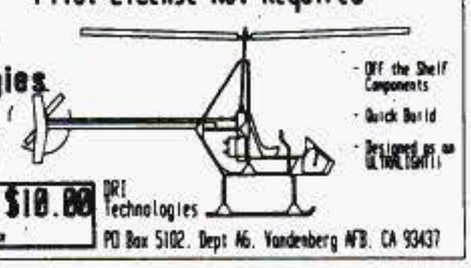
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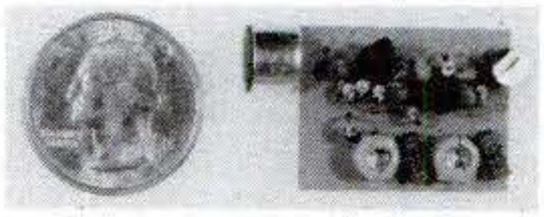

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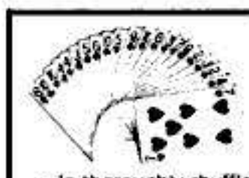

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# Looking Back...

**Sampling a century of POPULAR SCIENCE**

## 25 YEARS AGO — JULY 1966

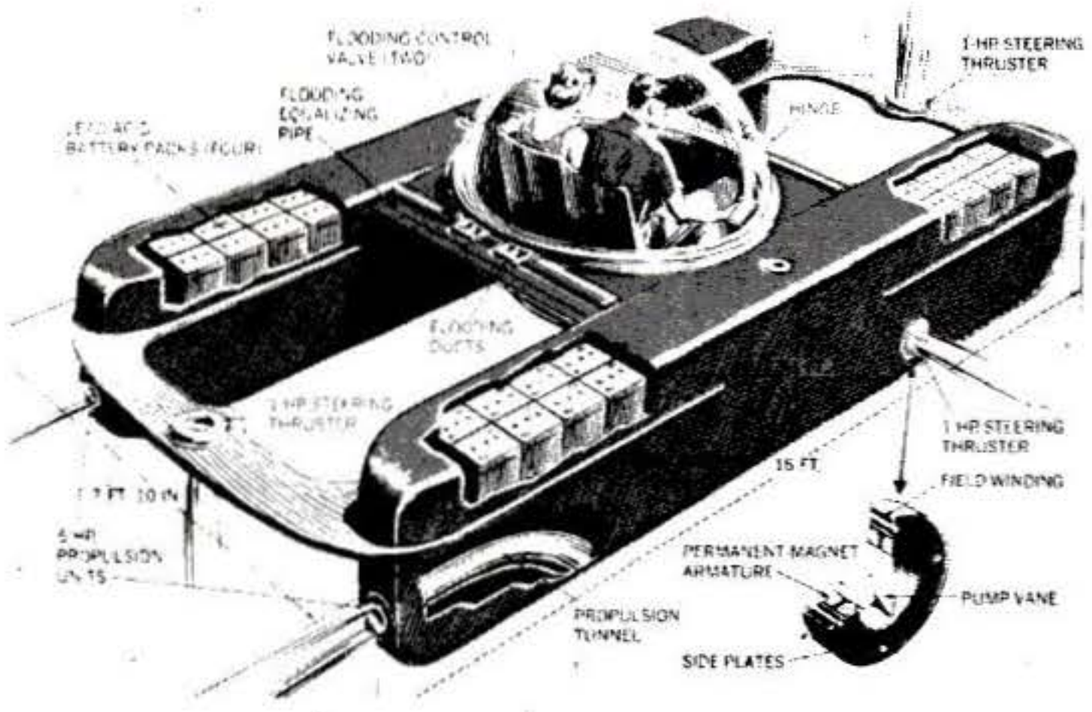
From the discovery that glass spheres get stronger as they go deeper comes a new craft for undersea pleasure cruising. All the equipment and machinery, except for the life-support system, will be in two fiberglass pontoons. Cross members will support the 56-inch-diameter sphere.

Since no electrical leads, rods, or other devices can be inserted through the 1½-inch-thick glass hull—to do so would weaken it—the sub will be controlled by photoelectric cells mounted outside the sphere and activated from inside by shining a flashlight on them or by turning simple discs to shade them from reflected light.

The most likely propulsion units are reversible axial-flow pumps. These are actually hollow-shaft three-phase AC electric motors and pumps combined. Constructed with their field windings potted in a plastic compound, the pumps are lubricated by sea water pushed through them by vanes in the hollow shafts.

Two pumps, one at the end of each pontoon, will push the sub through the water at three knots or better. Four other pumps, mounted in the sides of the pontoons and in the extreme front and back cross members, are "thrusters," designed for steering sideways or up and down.

Power for the pumps will be supplied by heavy 6- or 12-volt lead-acid batteries mounted on tracks in the pontoons' tops. The batteries will be topped with a protective coating of oil and will be left open to ambient pressure of the sea, eliminating heavy battery cases. The batteries are the heaviest weights aboard the vessel; by gently nudging them back and forth with a motor-driven lead screw, it will be possible to keep the sub in perfect trim. In an emergency, they can be dumped so the vessel can rise.




**In an emergency, the glass sphere of this submarine can be released to float to the surface.**

## 50 YEARS AGO — JULY 1941

Not long ago, CBS research men, working under Dr. Peter C. Goldmark, were well satisfied when they succeeded in transmitting a still photograph in natural colors by television. From that, they progressed to televising color movies. Today, action views of living subjects in colorful costumes are being put on the air.

To accomplish these "live pickups," Dr. Goldmark and his aides have designed a unique television camera. What it does is to transmit images as viewed through red, green, and blue-tinted gelatin, in swift succession. One of the secrets of its remarkable performance consists of a super-sensitive pickup, or scanning, tube. Side and overhead banks of cool fluorescent tubes, yielding intense light without the uncomfortable heat of conventional studio lamps, also help to solve the problem of illumination.

Home receivers for television in color and in black and white outwardly appear alike. Those for color, however, will contain a revolving disk tinted red, green, and blue. Conversion units may adapt present-day television sets for receiving natural hues. Color wheels in home receivers will be adjusted to turn exactly in synchronism with the color drum in the studio's television camera. Because the human eye retains an image for a fraction of a second, it will fuse the three colors. The result will be a full-color scene, with intermediate hues of the spectrum formed by combinations of the filter colors.

**A key feature of this television camera is a supersensitive pickup, or scanning, tube found in the camera's extension.**

The "Eye"—No Longer Color-Blind
5 Pick-up Tube Scans Image With Electron Beam
4 Image is Formed on Pick-up Tube
1 Light Rays Enter Camera Lens
6 Cable Carries Impulses From Pick-up Tube to Television Transmitter
2 45-Degree Mirror Reflects Light Rays Through Color Drum
3 Spinning Drum With Red, Green, and Blue Windows Separates Colors of Scene

## 100 YEARS AGO — JULY 1891

A large share, probably 20 percent, of the timber cut in this country is used by the railroads, and an important item is the quantity used for ties. With the purpose of lessening the drain upon our forest resources, the Forestry Division of the Department of Agriculture is endeavoring to lead the railroads to substitute iron ties for wood.

A report made by E. E. Russell, "The Substitution of Metal for Wood in Railroad Ties," furnishes companies with information in regard to the use of iron ties to facilitate their general adoption. The report gives detailed information respecting the use of different systems of iron ties in all quarters of the world. Outside of the United States and Canada, there are reportedly 25,000 miles of railroad laid with metal ties. In the United States, with a total mileage of 161,000, or four-ninths of the whole mileage of the world, there are only two miles of metal track.



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And if you're building your new home, remember that build ing electrically costs less. Because you don't need extra pipir for gas or oil. You should also know that advances in techno ogy are making electric applications more efficient. This hel conserve our energy resources, which contributes to a clean environment, now and in the future. If you'd like to know mo about energy saving programs in your area, contact your elect utility. We can promise you it won't be a waste of energy.

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